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AGRICULTURAL CHEMISTRY

RENDERED

SIMPLE FOR PRACTICAL PURPOSES,

ILLUSTRATED WITH

NOTES.

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CHELMSFORD: MEGGY AND CHALK.
LONDON: LONGMAN, BROWN, AND LONGMANS.

MDCCCXLIII.

191. c. 47.

CHELMSFORD:
PRINTED BY MEGGY AND CHALK, HIGH-STREET.

PREFACE.

THOUGH many works have during the last few years made their appearance with the intention of rendering the science of Agricultural Chemistry of practical importance to the farmer, most of them appear to be either too technically scientific or too empirical. To publish a small work in a series of numbers, in which the text will be unincumbered with scientific terms and definitions, is the intention of the writer, while for those who may desire some insight into the laws on which the practical information is founded, a series of notes will accompany the text, placed in every possible instance at the foot of the page.

There are many intelligent men whose habits would render the perusal of scientific details a most wearisome and unprofitable task, while there are others to whom such information would be a matter of interest and amusement. To serve as far as possible the ends and desires of these two classes, will be the object of the present little book on Agricultural Chemistry.

It would be well, were it impressed on the minds of all engaged in the practical application of scientific truths, that however they may think that they are making the most profitable use of their empirical knowledge, they can never be sure, they can never ascertain if they are doing their best, because they do not know, because they have not taken the trouble to learn—in the first place the facts themselves, and in the second the unalterable laws of nature, made known and reduced to practice for the good of mankind by the labors of a few scientific and industrious men.

There are many farmers in the habit of saying "I think I shall try some lime or some salt, or something else, on my land." You may naturally ask the speaker why he thinks it will be of use, he will perhaps reply, "Oh! I tried *nitre* or *gypsum* last year, and it did not do any good, I thought I might try the others this year." Now, without knowing why, the farmer had put nitre, gypsum, lime, or salt, upon his land, when perhaps the substance deficient and required by his crops might be bones or some other phosphate containing substance. He had spent perhaps five times the money and time necessary, which might all have been avoided by a little, a very little, information on the subject.

Farmers may say that they have no leisure for the reading and studying the ponderous works of the learned, and the education of many would render the thing impossible were time not wanting; seeing this, to overcome the difficulty, this little work has been prepared, it does not pretend to be original, it only hopes to be useful.

T. G. T.

DECEMBER, 1842.

CHAPTER I.

IMPORTANCE OF AGRICULTURE—ITS PRIMITIVE STATE —POPULATION A CAUSE OF IMPROVEMENT—PREJUDICE AN ENEMY TO IMPROVEMENT—SCIENTIFIC AIDS TO THE ARTS, CHEMISTRY—PLANTS REQUIRE FOOD—WHAT IS REQUIRED OF CHEMISTRY—TRUE PRINCIPLES IN CULTIVATION — ELEMENTS OF PLANTS—GENERAL SOURCES OF FOOD OF PLANTS.

THE science of Agriculture, having for its objects the supply of food for man, is of that importance to us all, that it deserves from those engaged in its pursuit the most profound attention. If we look at the annals of civilization in all ages of the world, we shall find Agriculture one of the first symptoms of the progress of knowledge, and a sure sign of an increased confidence of one man in another. A settled habitation, and the desire to obtain some sure source of food, first induce man in a wild state to cultivate his land. His knowledge is imperfect and his wants are few; he sows the seed of plants which he has been accustomed to devour, knowing from sure experience that in due time he will be rewarded with an increase sufficient for the wants of nature.

In the course of years, as his information increases and with it his wants, ideas present themselves, and improvement in all his plans is the result. He finds, that by the continued growth of his corn on the same spot, the increase diminishes, and is led to seek for some means to renew the fertility of his land. The refuse of the plants grown serves him, as the resource most within his power, with the means of restoring the fertility, which has been exhausted. Food, once the grand and only object of his wishes, now becomes, though still the most important, only *one* of the necessities of his life; clothing and all the wants of civilized life gradually find their way into his once so simple plans. New suggestions present themselves, and the chace having declined, he looks to his land for the supply of not only the necessities, but the luxuries of life. Agriculture by imperceptible steps becomes a science, and at the present day we find it is engaging justly the careful attention of all its cultivators.

The prejudice, however, of past times is difficult to overcome, and some cannot be persuaded to leave the old, and once good systems, of their ancestors. The increase of population brings with it new wants, when men were few compared with the extent of land, the simple means of procuring a supply were equal to the wants, and the plans then in practice were admirably suited to the purpose. Population has increased, and improvements have been adopted, so that what was a simple series of traditions has grown into an extensive science. Still it is most difficult to persuade men to change the plans which they have been taught to consider the best, and to put into use the modern improvements which other kindred sciences have discovered. But those who still resist what they consider innovations, will most assuredly find, that a new generation will surpass them, and that they will not be able to cope with men, who, laying aside the prejudices of the past, consent to make use of the powerful assistants, which science places in their hands. Who can deny that a man, who follows a rational plan, is more likely to succeed than he who, misguided by his ignorance, blindly stumbles in the dark with error, or at best, most imperfect rule as his companions ?

To attempt to improve a machine without knowing what it lacked would justly be deemed most absurd by all. But to strive to improve the soil in which we cultivate our food, without knowing what will serve the purpose, is daily practised. The fault of not knowing is perhaps not entirely that of the Farmer, it should have been the duty of those, who could have given him simple plans for his help, to have done so. And of late years we find many most useful works giving a general history of the means within the power of the practical man, and pointing out to him the best sources from whence to derive that help, which he requires for his purposes of cultivation.

The leading men of the land have stepped forward with a helping hand, science has used and is using her utmost endeavours, and it now rests with the actual cultivator of the soil to study the principles on which his science is founded.

Chemistry is the science which is capable of affording the most efficient aid to Agriculture, and we accordingly find the two gradually blending, so that shortly no one will be able to compete with his scientific neighbour, who from prejudice or idleness refuses to make himself acquainted with the laws brought to light.

Men of science may make known as far as they are able the laws of nature. They may place in the most evident light the strong necessity of being guided by true knowledge rather than by chance, but they can do no more, it rests with the actual cultivator, to prove how great are the benefits to be derived from a rational course of proceeding.

It does not require the aid of science to tell us that plants require food. Nor is it necessary to be profound to know that all food is not alike nourishing. But science has shown that all plants require certain sorts of nourishment, and that without these they will not flourish. Almost every plant has a different composition in some respect, and a variety of food or manure is therefore necessary.

It is well known that certain soils will not grow a particular sort of grain, but the reason is seldom asked. If it were, the answer would be that these particular soils are deficient in one ingredient that the plant requires : and should the deficiency be ascertained and the substance wanting added to the soil, there is no doubt but the plant would grow and flourish.

The great problem in Agriculture is to supply plants with the substances of which they are composed, in a form fit to be received and give nourishment.

The object of the present work is not to give a mere empirical account of the subject, but to seek to place before the reader, in a simple form, the phenomena of vegetable existence, the rational means of aiding the powers of life, and the most economical methods of supplying food to the plants cultivated.

It is however required of the farmer that he make himself familiar with the general laws of the sciences which are so wedded with his own, for no assistant but true and solid knowledge will ultimately be of service to him ; he must consent to go through the troublesome path at the commencement, and among the difficulties which beset him he will be rewarded at every step by knowledge, success, and the pleasure of doing good.

It has been noticed that as the population * of a

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* The population of England about doubles itself in a generation.

country increases, the products of the land in a natural or even ordinary state, as produced by Agriculture, are not sufficient to supply the demands for vegetable and animal food. The supply must be increased by artificially providing the plants which we cultivate with more of their proper nutriment. This supply must necessarily be suited to the nature and composition of the plant which it is desired to render more fruitful; before this can be accomplished it must be ascertained what substances are required, the methods of applying these, to discover what is beneficial and what is likely to prove injurious, and to make ourselves acquainted with states of vegetation in nature, the functions of the plants, that we may be able, by following the rational means pointed out by nature, to place the plants in the state most suitable to their several habitudes. The organs of plants most suited for food, and the nourishing qualities of these organs, are all points, which must be determined before a rational system of increase can be founded or put in practice.

The manner in which we are to proceed in these enquiries, the knowledge of the matters contained in plants, the various sources from whence a supply of nourishment can advantageously be obtained, the preparation and preservation of manures, are taught by Chemistry. Let us only look to the time when this science was in its infancy, and observe from period to period the improvements in all our domestic and national arrangements. Our streets are lighted by gas, produced from coal, which might have long lain useless in this respect, but for science; our merchandize is carried across the Atlantic in one-third of the time once required. And land which lay barren, the garden for brakes and brambles, glitters in the golden garments of the autumn, producing labour for the poor, luxury for the rich, and food for all men. The swampy marsh, that once sent forth its pestiferous vapors into the air, is good pasturage for flocks of healthy cattle; all may be obtained by application. England may, from her own resources, be supplied with food; most of the land in this country can and will be made to produce double, perhaps treble, its present crops.

Agricultural Chemistry is the science which teaches us to convert into food, for man and animals, the decayed remains of past ages.

We use for manure those substances, the remains of former generations,* which, having already served the purposes of life, are laid up as treasures for the support of future periods.

We give to plants what has been, and will again become, parts of their being; such substances, of the elements of which they are composed.

To feed a horse with coal would be as ridiculous as putting iron in a fire to be consumed. To manure plants with substances which they cannot assimilate, is equally absurd with the above.

We are sure that a horse cannot eat coals, we give him oats, hay, and those substances which being of the same composition† with his body, may by the processes of life become part of it. The same laws which hold good in the animal creation apply with equal force to the vegetable* part of the world.† If we consider the state of nature in ages far ago, when the earth was far less densely populated than at present, regarding also the state of Agriculture, we shall find it of the most simple kind.

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* Perhaps the atmosphere once contained more carbon than at present. The immense remains of vegetable productions, and the great expansion of leaf which the palm tribes possessed, lead to this supposition.

† The main constituents of the animal body are the same as those of plants. The fibrine, albumen, and casein, are of exactly the same composition as the flesh, blood, and serous fluids of animals. They only differ slightly in form, in chemical composition they are the same.

That the composition of plants may be more thoroughly understood, the nature of the elements and the forms in which they exist in plants and manures, must necessarily be explained and described.‡

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* The vegetable world seems to be the intermediate connexion between inorganic and organic nature. The substances which compose the animal tissues are in elementary composition the same as the vegetable; but it is the vegetable part of the creation, which, from ammonia and the other constituents of manure, form the starch, fibrine, and other similar bodies, which are directly applicable by mere digestion to the renewal of the used tissues in the animal body.

† That that which once existed on the earth in the form of gigantic vegetable and animal beings, is now elementarily in the form of man, is pretty evident,—witness the remains of the palms and antediluvian animals, and the increase of human population.

‡ The elements of plants, and the chemical forms in which they exist, are the following:—

Carbon,	Organic.	Carbon,	From the atmosphere and soil, as,	Carbonic acid, Water, and Ammonia.
Hydrogen,		Hydrogen,		
Oxygen,		Oxygen,		
Nitrogen,		Nitrogen,		
Potassium,	Inorganic.	Potassium,	From the soil alone.	
Sodium,		Sodium,		
Calcium,		Calcium,		
Magnesium,		Magnesium,		
Silicon,		Silicon,		
Aluminium,		Aluminium,		
Chlorine,		Chlorine,		
Sulphur,		Sulphur,		
Bromine,		Bromine,		
Iodine,		Iodine,		
Iron,		Iron,		
Manganese,		Manganese,		

The elementary bodies of which the whole organized world is chiefly composed, have received from Chemists the names of—

Oxygen,
Hydrogen,
Carbon,
Nitrogen,
Sulphur, and
Phosphorus.

Carbon exists in plants, as:—

Carbonic acid,
Organic acids,
Woody fibre,
Starch,
Gum,
Sugar,
Neutral substances,
Vegetable alkalies,
Oils, fats, etc.
Wax,
Essential oils,
Coloring matter,
Gluten,
Albumen,
Pollen,
Resins,
Hydrocyanic acid.

Hydrogen exists in all the above, except carbonic acid, and in—

Water, and Ammonia.

Oxygen exists in combination with carbon always, excepting in some essential oils and hydrocyanic acid; united to hydrogen as water, with metalloides and metals, as—

Oxygen as
- Nitric acid,
- Phosphoric acid,
- Sulphuric acid,
- Silica,
- Iron, oxide,
- Potassa,
- Soda,
- Magnesia,
- Alumina,
- Lime,
- Manganese oxide

Nitrogen exists in the following combinations:—

Nitrogen as
- Ammonia,
- Gluten,
- Albumen,
- Legumen,
- Organic acids,
- ——— bases,
- Volatile oils,
- Nitric acid,
- Hydrocyanic acid,
- Coloring matter.

They exist in plants, animals, the earth, air, and water, as it is found in our rivers and seas.

All plants being formed chiefly from these elementary bodies, it must be for us to supply those substances which contain them, for manure or food.

The great bulk of the atmosphere is composed of two gases in the state of simple mixture: they are called oxygen and nitrogen, the latter of which exists in much larger quantity in the air than the former; while in the substances which form the crust of the

Potassa exists as—
Potash as
- Salts of organic acids,
- Sulphate,
- Nitrate,
- Phosphate,
- Hydrochlorate,
- Hydriodide,
- Hydrobromide,
- Carbonate.

Soda exists as—
- Salts of organic acids,
- Sulphate,
- Nitrate,
- Hydrochlorate,
- Phosphate,
- Hydrochlorate,
- Hydriodate,
- Hydrobromate.

Magnesia as—
- Phosphate,
- Carbonate,
- Double phosphate with ammonia,
- Organic salts of

Lime as—
- Sulphate,
- Phosphate,
- Carbonate,
- Organic salts of

Silicon as—
- Silicic acid,
- Silicate of potash.

Alumina as—
- Phosphate.

Iron as—
- Phosphate,
- Oxide.

Manganese as—
- Oxide.

Sulphur as—
- Sulphuric acid,

and in the essential oils of mustard, horse radish, onions, garlic, etc.

Phosphorus exists as—
- Phosphoric acid in the phosphates.

Chlorine;—in all the chlorides.

Iodine and bromine chiefly in sea plants, as—
- Bromides,
- Iodides.

earth generally, oxygen constitutes the one-half.* Water, earth, and air are composed of one-half oxygen, an invisible and almost intangible substance, yet endowed with such important qualities, that it is the great cause of almost all the phenomena of vegetable and animal life. In animals it is the cause of heat. In plants germination is owing to its influence. It is the supporter of combustion, and fire would be extinguished without it; while all the changes in the elements of our earth are more or less owing to its action.

The other element of the atmosphere is called nitrogen, and in the condition in which it is there presented serves merely as means of diluting the oxygen, with which it is mixed.†

These are the two chief constituents of the atmosphere of our earth; but there exist in the air, in sufficiently large quantities to produce great effects, other bodies, which are the result of the respiration of animals, and the decay or putrefaction of organic substances. These substances do not form any very considerable part of the air; and though this is the case, their proportion in general is very constant.[*] They are continually being evolved into the air, but they do not increase in quantity: they are used by plants, and again become part of the organised world.

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* The quantity of oxygen in the materials of our earth is very great: almost all the soils, rocks, and minerals are compounds of oxygen. The atmosphere contains 21 per cent. of its volume. Carbonic acid, which forms so large a part of the food of plants, contains 72 per cent. of this element: every 90 pounds of water contain 80 of oxygen.

† Nitrogen gas, as it exists in the atmosphere, is supposed, by the generality of chemists, to be in that state perfectly inert. More nitrogen is found in the expired breath of man than the quantity inspired, which probably arises from the atmospheric air swallowed with the saliva; on which subject we shall speak more fully when treating of rumination. Nitrogen is absorbed by rain water in greater quantity, in proportion to what exists in atmospheric air, than oxygen; but this is the case with many other gases.

The continued respiration of animals, the combustion of fuel, and the decay of various matters, send into the atmosphere and supply to the soil immense quantities of carbonic acid,[†] which is the means of supplying plants with almost all the carbon which they contain.[‡] The carbonic acid sent forth by animal and other causes is decomposed by plants, its carbon being received into and made part of their tissues, and its oxygen being again returned to the air to combine again with fresh portions of carbon, and again to be evolved.

The other body which exists with carbonic acid in the atmosphere is ammonia,[§] a volatile compound produced in great quantities during the decomposition and putrefaction of all organic bodies which contain the elements of which it is composed. The bodies of animals, their dung and decaying vegetable matter, are, in the processes of putrefaction, sources of this substance. The composition of ammonia is admirably suited to supply plants with the means of forming those parts to which they owe their valuable qualities, as food for man.[*] Ammonia consists of nitrogen, the body spoken of as forming part of the air, and another element called hydrogen. As it contains *nitrogen*, a substance which all plants require, in a condition to be received as food, it is a most indispensable substance whether in the sources of nourishment to wild plants, or in the manure, which we give to increase the produce of vegetation.[†]

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[*] This is to say, the actual quantity in the great bulk of the atmosphere is the same. The distribution is sometimes unequal.

[†] Carbonic acid is a compound of oxygen and carbon. It is probably the only form in which carbon can be received into and become part of plants. It is a gas heavier than air, and is what is commonly called *foul air* or *choke damp*, by miners and others.

[‡] Carburetted hydrogen and carbonic oxide are supposed by some to give carbon to plants, but if so the quantity is probably very small. These two gases exist in the atmosphere. The former, carburetted hydrogen is the fire damp of miners, and the cause of the terrible explosions in mines.

[§] Ammonia is the same substance as hartshorn, and its carbonate is the common *smelling* salts of the shops. It is composed of carbon and nitrogen. The smell of stables in the morning is owing to exhalations of ammonia.

Ammonia exists in the atmosphere, and every shower which falls to the earth carries this body with it, and spreads it uniformly over the soil. While, on the other hand, the continued decay of dead matter sends ever fresh supplies, to be carried again to the soil. Ammonia contains 82½ per cent. of the most important element, nitrogen, and not only exists in the air but constitutes the most active part in all manures, produced by the decay of animal and vegetable bodies. As it is of the very utmost importance, it will be ever the problem in Agriculture to supply it in the cheapest and most tangible form, and the history of its properties and the states in which it exists in nature must occupy more of our attention in this place.

It is by no means an uninteresting thing to observe, by the help of a few calculations, the immense quantities of nitrogen that are continually being evolved by decaying bodies.* The flesh of animals contains nitrogen in very considerable quantities, and in its gradual decay this nitrogen is evolved in the form of ammonia. The flesh, hair, and skin of animals, contain 15½ per cent. of nitrogen; they are supplied with this from their food, and their food alone, and in process of time, when they die or decay, they return it again to the vegetable kingdom, from whence it was derived. For every thousand pounds of the animal matters above-named, which decay, 155 pounds of nitrogen are converted into ammonia, or some other form fitted for the food of plants. It may be said that very little flesh decays, it being used as food, but the same quantity of nitrogen, as is eaten by a full-grown man† in his food, is excreted from his body, and sooner or later his body itself must return to the earth, and its elements

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[*] Ammonia consists of 6 atoms of hydrogen and 2 atoms of nitrogen, or 3.205 hydrogen and 15.083 nitrogen by weight.

[†] Stable manure is very rich in ammonia, and supplies it to plants.

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* The flesh and blood of all animals are the same in actual composition, and contain for every 100 pounds of flesh 15 pounds of nitrogen.

Beef, (Playfair.)

Carbon	51.83
Hydrogen	7.57
Nitrogen	15.01
Oxygen	21.37
Ashes	4.23

Bullock's Blood, (Playfair.)

Carbon	51.95
Hydrogen	7.17
Nitrogen	15.07
Oxygen	21.39
Ashes	4.42

† The urine and other excretions of all animals, when they do not increase in size, contain the same quantity of nitrogen as is taken into the body. But if the animal be rapidly gaining flesh, more nitrogen is assimilated than the organs have lost in the use of the body, so that not so much is expelled as is consumed, but sooner or later this nitrogen must be returned to the soil and atmosphere, and as ammonia.

become the source of life for coming generations. As soon as life* is ended the chemical changes commence, and the body can quickly no more be known as the former temple of the soul. Its parts become in the changes of the seasons the food of plants and animals.

The great direct source, then, of nitrogen for plants is not from that which has been shown to exist in the atmosphere as nitrogen, but from the ammonia which is supplied from decaying bodies. To supply nitrogen to plants in cultivation, it will be well to bear in mind the general description here given of the states in which this element exists in the surface of the earth.

Plants may grow for generations in the same spot, and not be manured, and the ground, instead of being exhausted, will gradually increase in fertility for reasons which are obvious. We suppose to ourselves a plot of ground, on which is growing some grass. The grass grows and derives its nourishment from the air and the soil; it soon dies, and becomes decayed, but the remains of its decay are left to irrigate the soil on which it grew, and it in course of time becomes fruitful and increases in verdure. But there is a difference between a crop dying on the spot where it grew, and its parts being carried away altogether from the land. If we carry the nourishment from the land we must restore it; and if we regard vegetables and crops of all kinds as a means of simply changing the condition of matter, we shall have a tolerable idea of the truth.

Nitrogen exists in plants in various forms, but in those plants and parts of plants of more particular use in Agriculture, it is found in the form of albumen or some modification of the same body. Plants, being for the most part very simple, with regard to the number of substances which enter into their composition, are easily supplied with the elements they require. But besides the organic matters here described, there are small quantities of various salts, which must be present in a soil for a plant to thrive, but as these differ much in the various plants cultivated and growing wild, they will be treated of respectively when giving an account of the manure required for different grains, and the means of using it to the best advantage. As a general rule, the manures that arise from animals are a judicious application for those crops meant for their support. The modifications of albumen, of which we spoke above, have identically the same composition; they all contain the same quantity of nitrogen and the other elements. As a summary on what has been said on the composition and sources of nutrition of plants in general, it will be sufficient here to briefly enumerate what has been more fully stated.

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* During life there is a continued struggle between the *vis vitæ*, or vital force, and the chemical force. As soon as death supervenes, the changes in the elementary forms of matter commence, the atoms of which we were composed fly hither and thither. What to-day was an animal, to-morrow may form part of a plant.

Plants are composed of

OXYGEN,

which they derive from water and air; to supply which is of very little importance to the Agriculturist, as it is so bountifully provided by nature as always to exist in sufficient quantity.

HYDROGEN

Is the next element of which the vegetable kingdom is composed, but it likewise is so abundant that in the ordinary manures applied to land it exists in quantities sufficiently large. Water is composed of this element united with oxygen, it therefore plays a considerable part in the general economy of nature.

CARBON

Is the substance which plants contain as a chief constituent. Those parts of plants which contain no nitrogen consist of carbon combined with the elements of water. It forms part of those bodies also which contain nitrogen, but is united in a different manner. It exists widely in nature and plants are supplied with it freely from the atmosphere. It forms the greatest proportion of coal, and decomposing vegetables furnish it to their living generations in considerable quantities. It is also supplied by the respiration of animals, and the combustion of fuel. Carbon exists in all natural manures in large quantities.

NITROGEN

Is the most important of these organic constituents. It is most particularly requisite for plants, as a substance containing nitrogen is always formed in a plant before any increase takes place in its parts. It is supplied in nature in the form of ammonia in the atmosphere from the decay of animal and vegetable substances. It is yielded from the manures of animals and constitutes the chief nutritious ingredient of all vegetable productions. Wheat and cereal grains generally contain it in considerable quantities in the form of modifications of albumen, while those plants used for feeding cattle contain it in smaller proportion.

Wheat contains, more than any grain grown in this country, in the form of gluten, a modification of albumen. Nitrogen is supplied to plants naturally from the atmosphere, as ammonia, produced by the decay of other plants and animals—artificially, with the manure of animals, and various salts consisting chiefly of nitric acid in combination with potash, soda, or ammonia.

Ammonia is an alkali, and possesses the properties of soda and potash in a somewhat less degree. It is very volatile, and exists in the atmosphere, and in the rain. Rain water owes its soft properties to the presence of carbonate of ammonia and the partial absence of inorganic salts.

Those parts of plants and those grains also which are more particularly cultivated for the use of man are rich in products containing *nitrogen.*[*] The object in manuring these plants is to convey to them all those bodies which contain the element, nitrogen, in a condition fit to be received into the organs of the plant.

Plants, wheat, peas, barley, and oats are the food of man; manures containing great abundance of nitrogen are the food of these grains. Grass, tares, *linseed*[†] and turnips are given to cattle, they by vital force are made into flesh, which is again the food of man. So plants are the means of converting nitrogen containing manures into proper food for man. Those plants which we cultivate for our use are those which contain great proportions of nutritious parts.

Nitrogen[‡] is then the great source of nourishment for men and animals, and therefore the substance most required for the manure of plants.

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[*] Fibrin, albumen, casein, gluten, and many alkaloids and neutral bodies, to be treated of more fully.

[†] Linseed cake, after the oil is expressed, consists chiefly of woody fibre, and gummy matters, which produce *chiefly fat* in animals fed with it.

[‡] Liebig has proved that the nitrogen of plants when not obtained as manure, is conveyed to them through the atmosphere. The air always contains ammonia in the state of a carbonate. And not a shower falls but carries with it to the earth quantities of nitrogen which were suspended in it in the form of ammonia. All animal bodies, when they decay, give off the whole of the nitrogen which they contain, as ammonia, which, in a gaseous state, is carried

All rich manures contain this body in great quantities. The nutritive part of stable manure, which is called ammonia, contains nearly 85 per cent. of this nitrogen.

The nitrates of soda * and potash in such common use at present as manures contain great quantities of this element, so also does *guano*, † a substance produced on the western shores of South America, by the flocks of wild sea birds which frequent them.

The other organic elementary bodies mentioned above are also indispensable, but are supplied in such considerable quantities in ordinary manures that their consideration is not of that importance, (excepting the two last) viz. phosphorus and sulphur. For it has been said there are required in the nourishment of plants many salts, chiefly containing one or other of these bodies as their constituents, with which salts ‡ it is necessary

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into the air and deposited with the rain or snow on the earth. This is not the supposition of mere theory, but the confirmed observation of one of the greatest living chemists.

* There is very good reason to suppose that the beds of nitre found in various parts are the result of the decomposition and oxydation of animal matters. Saltpetre is made, or was in the time of the French revolution, in quantities sufficiently large to supply that government with gunpowder, by the putrefaction of animal matters in great beds in contact with lime and the atmospheric air.

† *Guano* is the excrement of the sea birds mentioned, mixed with large quantities, sometimes of the oxalates of lime, &c. The nutritious ingredient of this substance is a salt, called Urate of Ammonia, a substance very rich in nitrogen, and affording great increase in the crops of wheat (when it is pure and good, which now I find is seldom the case.)

‡ The saline ingredients of plants are very different. The oat

that these plants be supplied, if they are intended to grow vigorously, and produce good and heavy crops. To give instances of these things we need only mention the use of bones for manure, and this will afford a beautiful illustration of the use of past generations in the support of the present. In countries like England where corn has been grown for centuries, and where the population has increased to such an extent, the surface of the earth is in fact deprived of those substances which, by feeding plants, indirectly serve as food for man. If we asked ourselves whence came all the earth of the bones of all these men ? From the earth would be the answer; and the answer would in fact be correct; the plants we eat, collect the earthy parts of our bodies from the soil, and if the soil does not contain these earths and salts, the plants languish, because they cannot perform those functions for which they were created.

We therefore supply plants with *bone dust*,* and they assimilate this bone dust, and lay it up in their tissues as food for the living. And it is only by thus considering the composition of the plants, the produce of which we must increase, that we can at all regulate the nature of the manure.

(Avena Sativa) contains silica, the carbonates of lime and magnesia; alumina and the oxides of iron and maganese.

Barley *(Hordeum Vulgare)* contains phosphate of lime, the chief ingredient of bones.

Wheat contains, according to Henry, biphosphate of lime, phosphates of soda, lime, and magnesia, with some sulphates.

The hop *(Humulus Lupulus)* contains sulphates, hydrochlorates and phosphates of lime and oxide of iron—so all plants contain and require saline and earthy ingredients in their food.

* Bones consist chiefly of phosphates of lime and magnesia, and carbonate of lime, which almost all the cereal grains contain.

In the cultivation of all grains, in fact, of all plants, the nature of the soil* is of secondary consideration, if the soil contain in itself those bodies which the plants require, and which can alone supply those elements sought for and organised by the plants themselves.

In new countries, such as America, the soil has yielded crops of wheat for more than fifty successive years. The soil could suffer itself to be used without manure through all these years without being exhausted, but we must here consider, that probably since the creation, the earth in these spots had been receiving from the atmosphere its nutritious parts, and though, for many years, wheat might be grown without manure, it would in time be impossible to obtain another crop in the same land, because the previous ones had each removed a part of those substances which were requisite for the growth of such a plant as wheat. In this country, and others in like condition as regards population, the land has been long exhausted, and we must now put into the soil as manure the substances which by the vegetative process we intend to be made into food.

Almost all plants require a different kind of salts for their support, but they, one and all, must be supplied with the organic constituent, nitrogen. For it is to this substance that they owe in a greater or less degree their powers of nutrition, the luxuriance of their growth, and the fullness of their crops.

The conclusion to be drawn, and the fact to be observed is, that we must supply plants with the materials of which they are composed to manure them effectually.

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* When a chemist is applied to for the analysis of a soil, he need not be required to state the exact composition of the soil, but whether it be fit for the cultivation of any particular grain.

In some parts of the wine countries of the Rhine,* the cuttings of the vines are used as the staple manure, with immense success.

In this country straw is returned to the land, and affords straw in like manner to the crops that are to grow.

To manure the land is but to feed the plants, and to carry out the plan, to feed the plants advantageously we must give them what they can eat.

Potatoes† do not require the same salts as wheat. Nor does the potatoe contain the same quantity of nitrogen, but a very small proportion, and it is therefore but a secondary article of food in point of nutrition. Most soils contain many ingredients of plants of some kind or other, which will support crops of them for years. But there must be an interval between these crops, time must be given for the soil to become acted upon by the weather, and be made sufficiently decomposed for its elements to come in a fit state for assimilation.‡

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* Liebig's Organic Chem: applied to Agriculture.

† Potatoes do not contain more than 1.2 to 1.5 of nitrogenized substances. The analysis of potatoes by Lampadius found them to consist of—

Woody fibre	6.8	p. c.
Starch...........	12.9	—
Albumen..........	1.1	—
Gum.............	1.7	—
Water............	77.0	—
	99.5	
Loss......	0.5	

‡ The minerals which exist in the soil contain many salts and substances, which are of the utmost importance to the plants which grow in the soil where they exist. The streams which run down from the hills carry with them solutions of the various soils through

A crop of turnips between two crops of corn is beneficial, and why ? Not because the turnips give anything to the soil, they give time alone, which permits the nutritious parts, the salts, *et cetera*, to become disintegrated and made into a fit state for the food of the corn.

which they pass. And the soils themselves by the action of the weather become decomposed and their parts reduced to such a state that they can be taken up by the plants with which the land is planted. This subject will be noticed more fully in treating of *fallow*.

CHAPTER II.

THE MEDIA IN WHICH PLANTS EXIST—THE ATMOSPHERE AND THE EARTH—THE ULTIMATE AND PROXIMATE SOURCES OF THEIR FOOD.

THE invisible atmosphere of our globe is not as was once supposed a simple gas; it is on the contrary a mixture of nitrogen, oxygen, and carbonic acid, with the vapors of water, ammonia, and other bodies in minute quantities. It extends from the earth to a distance of about forty miles, and exerts a pressure on its surface of about fourteen pounds to the square inch.

The atmosphere is so constituted as to be the source of all the phenomena of animal and vegetable existence; the ingredients of which it is composed are of such universal use and activity that without it life like ours or that of plants could not exist. It is the medium in which we move, the substance which we breathe, and the channel by which we convey what our bodies do not require to the vegetable world.

The two chief constituents as regards the great bulk of the air have been described. The one, active and continually employed in the daily phenomena of our existence, the other, as regards its positive activity, of minor importance.*

The first of these two bodies is the substance which serves the purposes of respiration in animals, which is the source of combustion in all our fires, and the active agent in producing the decay of all organic bodies. This substance, it will be remembered, has been called oxygen, and for all the phenomena of life and of decay in death to proceed, it must be present in the air.

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* See note, page 14.

The carbonic acid formed during these processes of respiration, combustion, and decay, is the food of plants. Carbonic acid consists of oxygen and carbon, and plants have the power, as will be more fully shown, of separating these two substances, of taking the carbon to themselves and sending back the oxygen to the air.

Decay and combustion are only the means which prepare for the living plants the remains of the animals and vegetables which preceded them.

The leaves and branches of plants are spread forth into the air, and they derive from it the nourishment which is provided in the form of carbonic acid.

The thing will be understood when put in the following evident terms :—There are two tribes of beings, animals and vegetables. In the atmosphere there are two gases, one of which (oxygen) is necessary for animals, and is given out by plants ; the other (carbonic acid) is required by plants, and is produced by animals in life and from them in death for plants. If this latter accumulated it would be injurious to animals, but it is so useful to plants that its quantity in the air is never so great as to be hurtful to animals. So that the very life of animals is dependent on plants, and the existence of plants in some measure on animals.

Not a breath is expired from our bodies * but serves

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* The breath of man and animals contains carbonic acid. When atmospheric air is taken into the lungs, the oxygen which forms part of it is absorbed, and a volume of carbonic acid is evolved

its premeditated purpose in the creation. Not a stream flows * not a rock crumbles † to dust but to maintain the great and divinely conceived plans of harmony and universal good. If a little time is spared from our daily labour, if a small attention is given to make known to our minds some of the good and harmonious workings of the creative power, surely we shall not consider that time lost nor that labor misapplied, for as surely will our minds be more fitted for our daily duty, as well by prompting us to improvement as by schooling us, in observing the perfection of nature, to imitate her never-failing ways, and study her workings in her most secret recesses.

Were nature left to herself, if man did not interfere,‡ there are provided powers all capable in ruling the harmony which must exist to produce perfection.

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with rather more nitrogen than was received in the air inspired. This will be more fully explained when we come to speak of reanimation in animals.—166.⅔ (equal to about ½-lb.) grammes of carbon are sent into the air daily by a full-grown man in the form of carbonic acid. Essai de Statique Chimique desêtres organises. Dumas, 2nd edition.

* The springs percolating through beds of various rocks, and washing away the soluble salts, carry to the soil much that is nutritious and advantageous; they are used as renewals of fertility in irrigation.

† The decomposition of minerals and the desintegration of rocks have provided the great alluvial plains for the growth of food for man. The rich valleys and fruitful plains are formed as regards soil by the crumbling dust of the mountains.

‡ This is the case among savage nations. Sufficient food is provided by the chace and the wild productions of the trees and roots; and nature would provide for all the changes (for our world is supported by change) necessary to provide the food for wild animals.

The same matter, the very same weight of substance, is in this world as at the moment of its creation. If a man die, and thousands daily die, he goes to the grave; we need not ask for his soul, but his body commences again to prepare* itself to serve again the purposes of a vital power. It decays, and the atoms which composed it are scattered hither and thither, we know not where, but there remains in a few years a bone or so to mark the spot. Who has not walked over a common and seen a white bone here and there, signs of death, the remains of sheep which have died and there decayed.† Perhaps a contemplative man may have asked himself what became of the dead? Where their bodies went when they died? If they remained in the grave and useless?

Let us carry our thoughts a moment to the grave, and watch the workings of the laws which rule so truly. But before this, be it remembered our food does not differ from ourselves except in form, and that man, when his soul has fled, is simply a lump of matter, subject to the same acting causes as all other material things. Being dead, the bodies of animals begin to change, and the elements of which they are composed, assume forms which can again become food for the generations of the living. The animal form is simply constructed, if we regard it elementarily. The four substances of which we have said so much, make up all that wonderfully complicated thing, a human body. Were it not for life, we should be no more than oxygen, hydrogen, nitrogen, and carbon, and when we do die we are no more. In the grave, in the dead body, the changes of matter commence. The chemical laws, ever in a state of activity, continue to re-arrange its elements, and ultimately the only remains are a few bones, a little dust, carbonate of ammonia, and water.

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* As soon as the vital power is extinct, the chemical force gains the ascendant. The laws of matter, no longer controlled by those of life, proceed uninterruptedly and decay supervenes. Many stages of decomposition are passed through, but the ultimate products of the process are of the simplest form. These products are carbonic acid, water, and ammonia, with sulphuretted hydrogen (the gas of rotten eggs) and phosphuretted hydrogen, the origin of the fires seen in marshes, known by the names, Jack O'Lantern and *Ignis Fatuus.*

† Decay, éremacausis, putrefaction, and fermentation, are all certain sorts of decomposition, and to a certain extent are the same processes.

If we speak more closely we must also name two other gases, compounds of phosphorus and sulphur, with hydrogen. Wonderful as it may seem, our bodies when we die will ultimately be nothing more than carbonic acid and ammonia. These we know are the food of plants.

The bones and the dust, the inorganic remains, in the revolutions of ages, will be brought to serve the purposes of the living also, for they are simply phosphates of lime and magnesia, and chalk, the carbonate of lime. Carbonate of ammonia is volatile, and is carried into the air and divided by the winds; the bones are soluble, and the phosphates and carbonate of lime can be washed away. After one age and nothing will be left. The carbonate of ammonia has been washed to the earth by the rain. It has been received as food and again organised by plants. The phosphates of the bones are dissolved and presented in solution also to the roots, and again become part of the living structure. What was an animal of a former generation has become the food for a succeeding one; there is one continued harmonious interchange to preserve the uniform supply of matter to all created beings. The carbonic acid and the ammonia are sent into the air, they are brought from thence by the rain to the earth; the bones are washed from the places where they were deposited, and coming into contact with the roots of plants enter into their organization. These are the ultimate changes of matter in an organized form. But there are many intermediate ones.

If we grow a crop of wheat, how extremely interesting and useful is it for a moment to consider what a scattering and division of the elements we cause. Let us suppose to ourselves a piece of land well ploughed and prepared for a crop of wheat. If we manure it let us suppose with sprats. We sow our crop and the changes commence. The composition of the soil is sent us to afford all the nutriment which the wheat plant contains. We will take the following soil as an example as the one on which, after having manured with sprats, we intend to grow our wheat. This soil at the time of its analysis had not been manured for twelve years, and a rotation of crops had been removed in this order during the latter nine years:—1, beans; 2, barley; 3, potatoes; 4, winter barley, with red clover; 5, clover; 6, winter barley; 7, wheat; 8, oats; and during the last year it was allowed to be fallow.

The land consisted of a very fine clayey soil, and yielded to water, by washing, 0.013 soda, 0.002 lime, 0.012 magnesia, 0.009 sulphuric acid, 0.003 chlorine, with traces of silica and humus.* This very fruitful soil contained, in 100 parts—

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* Humus is the name given to vegetable matter when it has assumed by decay that homogeneous brown rotten aspect, peculiar to decayed substances.

Silica	64.517
Alumina	4.810
Peroxide and protoxide of iron	8.316
——— Manganese	0.800
Carbonate of lime (chalk)	9.403
——— of magnesia	10.361
Potash, chiefly combined with silica	0.100
Soda.	0.013
Phosphoric acid	1.221
Sulphuric acid	0.009
Chlorine	0.003
Humus	0.447
	100,000*

The crop of wheat grown on this soil would remove from it part of the potash, soda, lime, magnesia, alumina, iron, silica, sulphuric acid, phosphoric acid, and chlorine.† For wheat contains all these substances, and will not grow in land where they do not exist. The sprats which have been mixed with the land having such a composition as is suited by decay to produce ammonia, supply to the young plant all that may be necessary for a good crop. There is carbonic acid in the atmosphere, and ammonia in the soil produced by the decay of the sprats, and there are other

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* Liebig's Chemistry of Agriculture and Physiology.

† Potash is the substance which is contained in wood ashes. It is an alkali, soluble in water, and existing in soap; in wood ashes it is in the form of a carbonate, combined with carbonic acid.

Soda is the alkali found in the ashes of sea weeds; in common salt soda is saturated * with chlorine. It is a very useful manure in many of its combinations.

Lime is so well known that a definition is not necessary. It possesses the properties of soda and potash in a less degree, and will combine with acids in the same manner, depriving them at the same time of their acid properties. Chalk is lime combined with carbonic acid.

Magnesia is an earth somewhat resembling lime in its properties, and likewise saturates acids. Epsom salts are composed of magnesia and sulphuric acid. Magnesia is found always in sea water and in almost all soils.

Alumina is another of those kinds of substances which take away

* When a substance like soda is mixed with an acid till it loses all those properties which make it such, the acid and the soda are said to be saturated. If we add lime to vinegar, till the latter loses its smell, it will be saturated.

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the sour properties of acids. Common clay contains a great deal of alumina, and the alum of the shops is a compound of it with potash and sulphuric acid or vitriol (common name for sulphuric acid.)

IRON (common iron) when exposed to the air becomes rust (it combines with oxygen), and then is like these latter bodies in properties, it saturates acids and forms what are called salts. It exists in almost all soils, and when in excess in certain forms is the cause of rust in wheat.

SILICA has the properties of an acid, though sand, which consists of silica, does not taste sour, it has most other properties of an acid; it is not very soluble in water, scarcely so at all, but when in combination with soda or potash, is more so. Glass is composed of silica and soda or potash, and if either of the latter be in excess, the glass can be dissolved in water. The hard substance which covers the surface of common cane is silica. Silica exists in all soils, and almost all plants contain it.

SULPHURIC ACID is the common vitriol of our shops, and is composed or formed of sulphur (brimstone) and oxygen gas. If we burn a piece of sulphur in the air a suffocating gas is produced, which is the first step to the formation of sulphuric acid. This gas combines with more oxygen, and it then becomes sulphuric acid. This is an acid of most corrosive power, but as an instance of saturation, if we mix it with lime in sufficient quantity it becomes perfectly tasteless and harmless; it becomes, in fact, gypsum or sulphate of lime. The same effects are produced by the other bodies above described, viz.—Potash, soda, magnesia, iron oxide, and alumina.

PHOSPHORIC ACID. When fish putrefies in a dark place it appears luminous, and when by chemical processes this luminous substance is removed from the fish, it is found to be a most combustible body (phosphorus), so much so that it will consume of substances, (compounds of phosphorus and sulphur) yielded in their decay of immense benefit. The crop grows and becomes ripened, let us then observe what the all powerful vital force has done for us. We supplied the plants with some materials in the soil, which we wished made into wheat and straw. When the crop has grown and the corn is dressed and cleaned, it will have almost the same identical composition with the food which we supplied to it when a plant.

The flesh of animals and fishes has been analyzed and found to consist of the same elements as the nutritious part of wheat.

The manure which in this case we put upon our land had the following composition, in round numbers—

Carbon	51.96
Hydrogen	7.57
Nitrogen	15.01
Oxygen	21.37
Ashes[†]	4.23

itself, and it has such a great *attraction* or *desire* for oxygen, that it will combine with it whenever they are in contact. Phosphoric acid is the result. Bones contain phosphoric acid in union with lime, the phosphate of lime.

Chlorine. Common sea salt is a substance which every one knows; but few would suppose that one of its constituents is a most deleterious gas. There is a substance sold in druggists' shops called spirit of salt. When this spirit of salt is mixed with any substance, containing oxygen, chlorine is formed; and if the arrangement is complete, a yellow gas will be generated, which is most suffocating, and is chlorine. This chlorine combines, though not exactly in the same manner as the acids, with the bodies named above.[*]

[†] The ashes contain phosphates and sulphates, and resemble the ashes of the wheat.

[*] In a small work, which I am preparing, these various combinations will be more fully described. It will be a hand-book of Chemistry, for the purpose of instructing Agriculturists who may be inclined to study the elements of that science.—T. G. T.

Now our wheat having been ground and dressed is made into bread, and if we compare the relations of these two analyses the difference* will not be difficult to account for.

Bread has been analysed and was found to contain

Carbon	45.09
Hydrogen	6.54
Nitrogen and oxygen	45.12
Ashes	3.0
	100.00†

This is the composition of the common bread which is our daily food. We have therefore converted part of the soil in which we grew our wheat, by its help, into bread.

The wheat taken from the soil now progresses through other orders of changes. It is now the food for man, and he eats it to supply the loss of the tissues of his body. The carbon which the bread contains in the form of starch serves the purpose of maintaining the temperature of his body by combining with the oxygen in the atmospheric air which he draws into his lungs. We know that oxygen combines with carbon, or a compound of these two substances (carbonic acid) is sent into the air in the breath. The air which a man inspires contains in every 1000 pounds somewhat less than one pound. That which he expires contains a great deal more.

The sources of carbonic acid in the atmosphere are numerous, and the supply must necessarily be very constant. The respiration of animals is not the least important of these sources, and how beautiful is the ordination in the mutual benefits which the two great divisions of created beings bestow on each other. It is needless here to enter into calculations as to the quantity of carbonic acid sent continually into the atmosphere in the breath of man; it will be sufficient to observe, that the carbon eaten by animals in their food is converted in great measure into carbonic acid, and sent out of the body by the lungs.

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* The part of bread which contains nitrogen is the most nutritive, and has the same composition as flesh.

† Böckman.

Carbonic acid gas is to animals, when it is received into their lungs, a most deadly poison; not so, however, is the case with plants. The deadly poison which animals expel from them is food for the vegetable world. The quantity of carbon existing in the atmosphere, in the form of carbonic acid, is more than equal to all of that substance which is contained in the whole vegetable world, even taking into consideration the immense beds of coal, which are the remains of the vegetation of past ages.* So what is an excretion of one class of organized beings is the source of food to another.

Let us now turn our attention to the changes which take place in the other elements of the wheat which we grew. It has become the food for man, still it is not wholly lost to the vegetable world. We have seen that part of the carbon which it contains is returned again to the air through the breath; the nitrogen and the other elements are likewise restored, but in a different form. The most effectual natural manure, the strongest dung which we use is derived from the solid and liquid excrements of man. Almost all the nitrogen taken in the food of man goes again to the soil in the urine; it exists in this fluid in different forms, but by the processes of putrefaction it is again converted into ammonia. Ammonia we know is one, most probably the chief source of nitrogen which plants possess, and the nitrogen, having served the purposes of the body, returns to its original form, and with it we manure our plants. Nothing is ever lost in nature, and though this very powerful manure is not collected with sufficient care, the ammonia is in time returned to the soil, not however to benefit individuals, but to serve the general purposes of vegetation * The ele-

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* Liebig's Organic Chemistry, app. to Agriculture.

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* How important is this to the Farmer! Why does he allow so nutritious an article to be wasted in such enormous quantities? Not only the urine and excrementitious matter of man but of animals should be regarded; and a most practical and beneficial application has been made of this in feeding cattle on the land where the crop is grown instead of having the food carted from the land, and when made into manure again carried back. How much time, labor, and manure, are wasted by this latter method of procedure. Farmers are aware of the advantage of feeding the stock on the land with the growing crop, giving them at the same time other food.

In the report of the Braintree Farmers' Club, with which I have been politely supplied by Mr. W. Hutley, an active Member of its Committee, the following opinion, agreed to by the Club, is published:—

"That folding sheep is very beneficial to the land, and that a "portion of artificial food, with the tares, clover, &c. will bring "a remuneration, not as regards stock only, but in the improve-"ment and benefit of the soil, and then such benefit will be seen, "not only in the next succeeding, but for many successive crops, "and will, on calculation, be found more economical than making "manure in the yards, when it has to be carted to land at a con-"siderable distance, the expence of carrying, spreading, ploughing "in, &c. being taken into consideration."

What the nature of the artificial food should be, depends much on the kind of crop desired to succeed the folding. Mr. Jonathan Hutley fed one acre of clover, using 1.000 of oil cake, another using 10 quarters of beans, and another with 10 quarters of peas. The succeeding crop of wheat was better on that acre fed with oil cake.

This of course depends not on the organic constituents of the oil ments of the wheat have gone through many changes, they were the sprats with which we manured our land. They became, when devoured as wheat which we had grown, part of a living animal. When they had served their purposes in the animal economy, they became again dead or unorganized matter, ready for the nutrition of plants in the forms so often alluded to. The changes can at once be seen in the following table :—

CARBON, HYDROGEN, NITROGEN, OXYGEN, PHOSPHORUS, and SULPHUR.

The composition of the sprats.

The elements which need be taken into calculation assume in the soil these forms, receiving oxygen from the air :—

$\left.\begin{array}{l}\text{CARBON,}\\ \text{OXYGEN}\end{array}\right\}$ CARBONIC ACID.

$\left.\begin{array}{l}\text{NITROGEN}\\ \text{HYDROGEN}\end{array}\right\}$ AMMONIA.

$\left.\begin{array}{l}\text{PHOSPHORIC ACID}\\ \text{SULPHURIC ACID}\end{array}\right\}$ combined with the substances in the soil.

The carbonic acid gives its carbon to the wheat.

The ammonia supplies nitrogen and hydrogen.

The soil supplies the inorganic constituents and the wheat plant flourishes.

The elements are now again arranged as organised matter. Wheat contains—

Carbon, Hydrogen, Nitrogen, Oxygen.

It becomes the food of animals (man)

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cake, but on the inorganic compounds which exist in it, and which pass out of the cattle after digestion. The excrements of animals fed with oil cake would contain sulphate of potash, chloride of potassium, phosphate of magnesia, sulphate of lime, silica, phosphate of potash. The results of the experiment accord perfectly with theory, for the wheat plant requires these substances.

The breath contains	The excrements contain
Carbonic acid.	Ammonia and the inorganic constituents.

The straw of the wheat is also manure.

The decay of animal and vegetable bodies which contain nitrogen, supply that ammonia found in the atmosphere. The carbon which they contain, combining with oxygen, supplies carbonic acid, which the respiration of animals is also continually producing. The excrements too of animals yield again their nitrogen, and the circle of changes ever turns on, regular in its laws, as the planets in their courses ; silently and performed by invisible powers and agents, the ends of nature are fulfilled, filling our minds with wonder, confidence, and gratitude.

Few men dream of the great operations performed in the invisible atmosphere in which we move, and many a lip would smile in incredulity if it were said that the great loads of our railroads were dragged along by the weight of this invisible gas. Let not such knowledge be considered trivial ; because the results appear distant they are not the less important ; if we know the secret workings of nature we are surely more likely to succeed when we endeavour to imitate her. If our minds are drawn for a moment to consider what is invisibly going on around us, they will be more fitted in a crisis to account for any failure in our undertakings, and more ready to propose a remedy for any errors caused by our inadvertence. The laws of nature never fail, and if we follow them truly, our plans may likewise be infallible.

Of the other sources of carbonic acid in the atmosphere we have not yet said sufficient. When wood and coal are consumed, all the carbon which they contain is sent into the air as carbonic acid. Strange as it may appear, while we are burning the oak log on our winter fire, we are providing nourishment for the acorn which once grew on its branches. In the densely populated country where we live, it can be imagined what immense quantities of this gas are sent into the air, when we consider that every ton of wood which is burned provides ten hundred weight of carbon in the form of carbonic acid.

The coal which we burn also is converted into carbonic acid, nor is this substance the only one likely to be of benefit which is produced in the combustion of coal; most species of coal contain sulphur in some one or other of its forms of combination, and nitrogen likewise exists in most varieties; accordingly there are found in the soot, salts of ammonia, produced by the contained nitrogen and sulphurous or sulphuric acid, in combination with this alkali. The neighbourhoods of great cities are doubtless indebted to this circumstance as one of the causes of their fertility, for much carbonate and sulphate of ammonia are carried as smoke into the atmosphere, and deposited in the surrounding soils.

These are the sources of carbonic acid and ammonia in the atmosphere, connected with the population of the earth, but there are other great and continual supplies independent of man or animated nature. There are many active volcanoes in America, continually evolving carbonic acid, and the continents of Europe and America abound in mineral springs, which send forth such quantities as to have the appearance of boiling as they issue from the earth; it has been calculated (Bischof) that the mineral springs in the Eifel, a mountainous district near the Rhine, in Germany, send daily into the air more than 110.000 pounds of carbonic acid. Carbonic acid may be recognised in the *foul* *air* which collects in the bottoms of wells. There are in many places likewise caves which are more or less filled; one more particularly celebrated is the Grotto of Dogs, in Italy, so called because dogs or any small animals when thrown into it are affected with stupor, and if not immediately removed die, while man from his erect posture, not being subjected to the deleterious effects of the carbonic acid as it escapes from the ground, feels no inconvenience.

In this general and cursory description which we have endeavoured to give of the composition of our atmosphere, and the sources from whence these useful constituents of its composition are derived, we cannot have failed to observe the beauty of design displayed; the death and destruction of one generation being the support of another, and the luxuries of man tending, unknown to himself, to carry out the great plans of nature. The coal which to-day we burn in our chambers, may to-morrow be decorating the earth in the form of a flower, or supplying food to the crops which we are cultivating round our dwellings.

The ammonia and the carbonic acid are the food for plants. They are the excrements of animals. The carbonic acid from our fires is one great source of the wood which we are burning. The atmosphere is supplied with the organic food of plants chiefly by the decay and oxydation of organic matter.

The atmosphere is placed almost beyond the power of man as regards its component parts, though by the cultivation and draining of morasses its physical properties can be changed, and a wet and unwholesome climate may, by the persevering efforts of man, become comparatively salubrious and dry. In boggy places where vegetable matter is continually decaying, and stagnant water putrefying, most noxious vapours and gases are generated; and most assuredly many of the diseases to which our cattle are subject arise from the wet state of pasture, or the noxious miasmata escaping from putrefying vegetable or animal matters. The atmosphere is not only the medium for supplying our bodies and those of plants with the necessities of our and their organization, but is the receptacle for all the germs of disease arising from the gaseous exhalations from putrefying bodies. It is well known to chemists that a substance in a state of putrefaction or fermentation will cause the same change to progress in any other substance, capable of such an action, as the putrefying substance is itself undergoing at the moment of contact; and that the action once induced, the exciting cause may be removed without arresting the commotion which it was the cause of commencing. If we put into beer or sweetwort a small quantity of yeast, it will be sufficient to cause fermentation in an indefinite quantity of this fluid. A piece of putrefying flesh placed in a room full of fresh meat would soon cause the whole quantity to become infected.

The bearings of this law may at first sight appear to be very distant from the farmer; when considered truly, however, they are of the utmost importance to him, whether it be in preventing disease among his cattle, by keeping the atmosphere of the houses in which they are confined free from the noxious exhalations of their putrefying manure, or in draining the pastures and feeding places, so that no disease may be caused in their feet by the contact of putrefying matter. For assuredly the feet of sheep and other domesticated animals are subject to diseases caused solely by inattention to cleanliness and dryness. When cattle, nay, when stock of any kind, alive or dead, are kept in places where substances are undergoing the putrefactive fermentation, they are liable to become affected, and to a considerable extent. It must be remembered that all bodies kept in closed rooms are in fact in an atmosphere peculiar to themselves; and if we put a load of hay in a loft over a stable where straw and other matters are mouldering away, we shall soon find our hay getting *musty* also. The same facts on an enlarged scale are observed in a damp and marshy country, where agues and other fevers prevail, for the vapors, continually rising, influence to an incredible extent the salubrity of the air, not only as affects the animal but the vegetable world. The circulation of air among plants as well as animals is of paramount importance; wheat is far less subject to mildew in open clear situations than when grown in low close districts, and even that slight difference produced in the manner of sowing is said to be a matter of consideration, for wheat sown by drilling is less subject to the mildew. The climate of a country, and the general state of the atmosphere, can be altered materially by draining and cultivating the land. And no piece of bog, however small, should be allowed to remain on a farm, for though the loss be small as regards the actual quantity of the land, it cannot be imagined what harm such a germ of putrefaction may be capable of producing.* To estimate the harm which may be done by this means, we will take a case, which though not exactly parallel, is sufficiently so to illustrate our meaning. If we take a small particle of the matter of small pox, so small as to be almost invisible, and with it we inoculate a child, a sore would be produced, and from this sore fifty or more persons could be infected with the disease, and the extent would, by continuing such means, be indefinite. The small particle would be sufficient to render diseased an indefinite number of persons.

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* For "bodies regarded as absolutely indifferent in organic chemistry on account of their possessing no prominent chemical characters, when placed in contact with one another, mutually decompose one another. Their constituents arrange themselves in a peculiar manner, so as to form new combinations; a complex atom dividing into two or more atoms of less complex constitution, in consequence of a mere disturbance in the attraction of their elements."—Liebig.

Sufficient has been said to make evident the great necessity of endeavouring by all means in our power to preserve the salubrity of the atmosphere, and it is surprising to what an extent we are capable so to do; and this not only in our farm yards and buildings but in wide and extensive tracts of country.

We cannot materially alter the elementary composition of the air, but we may free it, or prevent it from receiving too great quantities of noxious aqueous and putrefactive vapors.

The temperature* of the atmosphere in our islands is extremely subject to change within certain limits, but the cold or heat is never so intense as in continental countries. The effects of the heat of the earth, or from it of the atmosphere,† are of the greatest importance in the phenomena of the world. Rain, dew, and almost all the meteorological phenomena, are caused by the changes of temperature continually taking place. The quantity of aqueous vapour in the atmosphere is ever changing, and the quantity of rain which falls in this county is seldom less at an average than one inch per month, nor more than six inches.

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* The temperature at the earth's surface is greatest; it is diminished as we ascend; in the lower strata in the rate of one degree of the thermometer for every 350 feet.

† The atmosphere is heated by contact with the earth; the higher therefore we are from the level of the earth the colder it becomes.

The distribution of water in the atmosphere is performed by laws of the most beautiful exactitude, and the formation of dew is perhaps one of the most exquisite adaptations of infinite power and foresight. In a cloudy night, when there is a probability of rain, no dew falls, but should the sky be clear, and hence the probability of rain be lessened, then the dew commences to fall. The reason of this fact is simple and evident; dew, or watery vapour, held in solution in the atmosphere, is condensed only on bodies which are colder than itself; in a clear night the heat contained in the substances on the surface of the globe is *radiated*, or passes away into the space of the atmosphere. As the bodies become colder than the air from the loss of their heat by radiation, they condense more of the water which is contained in the air, and as night proceeds the bodies exposed become colder, and the deposition of dew is increased. The slightest blind or obstruction of any kind is capable of retarding the radiation of heat, and consequently the quantity of dew under such circumstances would be in like manner diminished, hence it happens, that on a night when the sky is cloudy no dew is formed, but on the contrary, in a clear and calm night, when the heavens are free from clouds, radiation goes on with rapidity, and in like manner the deposition of dew is increased. In our climate the falling of dew commences as evening advances, and progresses through the night. Many substances radiate more freely than others, and on them we find the greatest deposition of dew; polished metallic surfaces are bad radiators, and keep hot a long time, hence they are said to be better for the exteriors of those vessels in which it is desired to keep anything warm, as teapots, *et cetera.* Dew is composed of water, containing in solution carbonic acid, and probably, though experiment has not proved it, like rain it may carry with it ammonia to the soil. If in the middle of a clear cloudless night, the sky should become suddenly overcast, the dew already deposited on the objects of the earth, would disappear. It is probable that the fertility of soils depends in some degree on their capability of radiation. Aristotle supposed that dew was, as it were, a rain from the lower parts of the atmosphere.

The phenomena of rain are as follow:—Watery vapor is continually floating in the atmosphere, and as the air in different parts of the earth's surface is by no means of the same temperature, so its capability of holding in solution aqueous vapor is greater or less. When two bodies of air, one of which is warm and saturated with water, and another cold, but likewise saturated, come in contact, the former is so cooled by the admixture of the latter, that it can no longer hold in solution the same quantity of aqueous vapor, and a deposition or fall of rain is the result.

The phenomena of snow and hail are not essentially different in their origin, the watery vapor being frozen in different conditions. The effects of frost upon the land are most beneficial, and the alternate freezing and thawing of a soil tend to render it pervious to the air, and to free it from the eggs and *larvæ* of noxious insects.

But on the large scale we can have very little influence in producing these phenomena, or in aiding or retarding artificially the effects of heat. We can only choose the moments of action most suited to the development of our plans. Some situations are warmer, and may be more suited from such causes to our wants and certainly much may be done by judiciously sheltering our lands and fields by plantations, hedges, or banks. Still these means are very limited, and the only plan of overcoming the difficulty is to choose such plants for our cultivation, and animals for our stock, which from constitution are able to bear its inclemency; or by gradually naturalising more delicate tribes, we may by degrees bring them to be able to suit themselves to the vicissitudes of our changing climate. It is impossible in a country like England to prognosticate with any degree of certainty the state of the weather, when we have often in one day spring, summer, autumn, and winter.

We have seen that the composition of the atmosphere is in every respect suited to the purposes of life and existence, and we shall find likewise that its mechanical or physical laws are no less adapted to the ends desired, for the general diffusion of each ingredient as it is escaping into the air from the spot where it was generated, that no accumulation may take place of any one of its gaseous constituents. The oxygen gas separated from the carbonic acid by the plants, is diffused and mixed universally over the face of the earth, either by the winds or by a certain property which all gases possess, that of mutual diffusion.*

The food of plants which they derive from the atmosphere is always present and can never be exhausted.

The soil next comes beneath our consideration, and as it is the only medium through which we can artificially supply our plants with food, it deserves a much more particular attention.

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* That is to say, if there were two chambers filled with two different gases, at the distance of a mile (or more or less) connected only by the means of a very narrow pipe, after a certain period, if we examined the gas, we should find in each chamber a mixture in quantitative proportions of the two gases.

The soil is adapted from its mechanical formation to give support to the plant,—to convey to the roots which permeate its substance, air and water containing food; it is porous that water and air may enter, yet sufficiently firm to give attachment to the beings which it supports. It is composed of substances of greater or less solubility, for the most part yet not always, needful to the well being of the plant, those ingredients of a soil most required for the nutrition of the vegetable, being more soluble than some others less important.

Soils are the receptacles of the food of plants. They require to be so mechanically constructed that this food which they contain may be so prepared by certain chemical and physical agents as to be in a state most suited to be received by the organs of plants, that is they should be sufficiently porous and permeable to allow the entrance of the atmospheric air, and the percolation of water; at the same time they must be so adhesive and retentive as to retain moisture for long periods. Soils, composed of due admixtures of sandy or siliceous earths with calcareous or chalky and clayey,* are those, which from their mechanical composition are most suited to the possession of these qualifications.

If a soil contain too much sand without a sufficient proportion of the two other ingredients, it is for the most part barren and dry. By the addition of clay to such a soil we improve it, and by increasing its adhesive and absorbent qualities we render it fertile. The adhesive properties of clay, and the power which it has of receiving and retaining organic matter and ammonia are owing to the quantity which it contains of the substance called alumina.

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* Though we only here include these three ingredients, we would remark that the mechanical properties of a soil in many instances are modified by the presence of vegetable substances, oxides of iron, magnesia, and other bodies.

The sandy and barren soils of many parts of Norfolk are rendered fruitful and productive, by raising up and admixing the rich calcareous marl on which they rest. Marl * contains chalk, alumina, and sand, but the most abundant of these ingredients is the chalk. In very many parts of Essex and Suffolk, the soils vary so much, that while one field is rich and fertile, containing large quantities of marl, another in juxta-position is barren, sandy, and unfruitful. It is by the due admixture of the sandy with the aluminous and calcareous soils, and a due proportion of organic matter, that those soils called fertile *loams* are formed.

While on the one hand these sandy and dry soils are improved by the addition of more tenacious and absorbent matters, soils containing these latter in great abundance are rendered fruitful, and workable with ease, when mixed and manured with sand.

Those soils which, for example, are formed in the London clay, are altered from their natural adhesive and sticky condition to one of great fertility by the admixture of sand; and in those parts of Essex, Suffolk, and Norfolk, which are on the skirts of the London clay, where beds of sand and the plastic clay abound, fertile loams are formed by the addition of the sand. In situations where the soils are formed from the decay of the rocks and masses of earth forming the new red sandstone formations, they are remarkable for their general fertility and the ease with which they are worked, more particularly when the sand is in contact with the red clay and marl; they also produce most capital pasture, for example, in that part of Warwickshire called the "county of Coventry." If we find a soil sticky, tenacious, and difficult to work when wet, and in dry weather baking into a hard and compact cement-like mass, this soil may be improved by the addition of sand.

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* Sprengel, a celebrated and most persevering German agriculturist and chemist, to whose valuable works we shall frequently have occasion to refer, has made analyses of several kinds of marl. Six different kinds of marl examined by him contained from one to ten per cent of alumina; from eight to eighty five per cent. of chalk or carbonate of lime, and from five to seventy-eight per cent. of sand and siliceous earth.

By the due proportions of these ingredients in soils, their mechanical fertility is produced, and as far as this property is concerned they are capable of producing crops as long as they contain other substances, of organic and mineral origin, which are required by plants in the organization of their tissues, and of which we shall treat hereafter, as a subject of the greatest moment.

When these three substances, sand, clay, and lime, which may be called the foundation of all good soils, are present in adequate proportions, the soil as regards its mechanical composition is good, but where there is a deficiency of lime or alumina, the soil is generally hungry, barren, and dry.

The following are two analyses of soils; the former a barren, dry, and unfruitful one; the latter remarkable for its fertility.

Silica and coarse siliceous sand	95.778
Alumina	0.320
Lime	0.286
Protoxide and peroxide of iron	0.400
Peroxide of manganese	a trace
Magnesia	0.060
Soda	0.036
Potash	a trace
Phosphoric acid	a trace
Sulphuric acid	a trace
Chlorine in common salt	0.052
Humus	0.768
Vegetable remains	2.300
	100.000

In the foregoing numbers it is sufficient to remark the large quantity of the first and the great paucity of the two following ingredients, and compare the numbers with those contained in the analysis of the fruitful soil.

Silica and fine siliceous sand	64.800
Alumina	5.700
Lime	5.880
Peroxide of Iron	6.100
Peroxide of Manganese	0.090
Magnesia	0.840
Potash, chiefly in union with Silica	0.210
Soda ditto	0.393
Phosphoric acid combined with lime	0.430
Sulphuric acid ditto	0.210
Chlorine in common salt	0.201
Carbonic acid combined with lime	3.920
Humus soluble in alkalies	2 540
Humus	5.600
Nitrogenous matter	1.582
Water	1.500
	100.000*

Apart from the other ingredients of this soil we see that the first three bear a very different relation to each other than in the former analysis. Of the former soil the amount of lime and alumina does not make more than ½ p. c., while the latter contains more than ten per cent.

This may be considered as a specimen of a most fruitful soil, corn having been grown on this land without manure for seventy years. The fertility is kept up by turning up now and then the subsoil, and by fallowing. The subsoil extends to a depth of from six to twelve feet, and has the same composition as that given.

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* Sprengel.

The foundation of all soils is necessarily derived from the superficial strata of the earth, from rocks raised by volcanic or other cause above the surface, and from the vegetable and animal remains, derived in the first instance from the air, by the vital and chemical powers of these two kingdoms of beings.

There are provided in the substances of the rocks, minerals and gases that exist on or form the surface of our globe, all the elements necessary for the support of life. If a plant contained three substances, A, B, and C, it could not grow in a soil which consisted of three other bodies, D, E, F; but if to the soil which contained the three last we added A, B, and C, then our plant would grow, and those ingredients not found in the plant would afford mechanical support. Of course no plant contains any element which does not exist in some mineral or rock, or in the atmosphere.

The aqueous and igneous rocks of the earth are characterised as well by the chemical composition of the minerals of which they are formed, as by their other properties of color, weight, porosity, and hardness.*

Geologists have classified the rocks into certain groups from the age or period at which they are supposed to have been formed.

The composition of a soil depends, as regards the quantity and nature of its constituents, on the rocks or strata of rocks from which it is derived. It is by the crumbling and disintegration of these rocks and masses of earth that the soils of our pastures and corn fields are formed.

That sort of soil which from the nature of its ingredients we find producing certain tribes of plants we may be certain contains in its substance the same salts and earths, as we should find in the ashes of the same plants when destroyed by fire.

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* For an excellent general description of the nature and distribution of the aqueous rocks in this country, and the soils produced by their decay, the reader is recommended to consult Mr. Johnston's work on the subject, page 355, and Morton on Soils.

The chemical nature of all soils must be such as to present in a soluble state all the ingredients which the plants grown in them contain; they must possess a certain degree of absorbent power; they must not contain ingredients which are positively injurious to vegetation, as salts of iron; and they must contain within themselves such remains of minerals or earths which can yield by degrees, by the action of the air and water, the materials removed in the crops. These properties constitute fertility.

The situations chosen by certain tribes of plants or found to abound in them, are generally characterised by some peculiarity in mechanical or chemical composition.

The atmosphere is in common the dwelling of all tribes of vegetables, and within moderate bounds as regards elevation and latitude, has not only its temperature and physical properties the same, but has always the same chemical composition, and is capable of affording to plants its component parts, which they all require; the case, however, is totally the reverse with regard to soils, every one of which differs more or less from another. Some are naturally dry and arid, composed chiefly of sand, and these we find tenanted by those peculiar tribes of plants whose habits are suited to such a dwelling, and whose constituent parts can be obtained from it. Others are boggy and wet, and they are in like manner occupied with certain genera which flourish only in such situations. These latter are formed by the accumulation for ages of the remains of plants which have grown and partially decayed in the same spot. In most bogs this is the case,—half decayed vegetable matter becomes saturated with water and forms *peat* bogs, the farther decay of such masses of semi-decomposed vegetable matter, being prevented by the presence of a substance similar to that found in the bark of the oak, and used for tanning. This *tannin*, as it is called, so preserves the various vegetable fibres in a state of tough elasticity, that layer after layer is deposited by the growth and decay of new plants, till a deep peat bog is the result. When peat land is properly drained, however, and supplied with inorganic earths, such as clay or marl, it forms a rich and fertile soil.

The nature of a soil can be tolerably well known by observing the general nature of the plants which flourish in it, and though this cannot always be depended upon with absolute certainty, still much may be inferred, and two or more spots of ground bearing the same plant may be supposed to be very analogous in their most important properties. If, for example, we find a soil abounding with the common Coltsfoot,* we may be sure that the soil is clayey, and abounding in alumina. The Coltsfoot abounds in the blue clay lands.

In places where the Fox-glove† abounds, we may in like manner be certain that the soil contains potash ; accordingly we find this plant luxuriating in the *debris* of Felspar and Basaltic rocks. In the counties of Norfolk and Suffolk, it is seldom or never seen.‡ It abounds in nitrates, and we find it frequently on old walls, growing in heaps of old lime rubbish.

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* Common Coltsfoot (Tussilago farfara) is a plant well known and abounding in moist clay soils and alum grounds; it blooms in March and April, bearing yellow flowers.

† Fox glove (Digitalis purpurea), a well known and handsome plant. It flowers in June and July, and exhausts the soil of potash particularly.

‡ Hooker's British Flora.

Other plants said to be characteristic of clay or argillaceous soils, are the narrow-leaved Bird's Foot Trefoil,* which abounds in the sides of ditches, and moist spots in clay land, and another species of the same plant, the *Lotus corniculatus*,† every where abundant, but particularly so in clay lands. The common Soap Wort‡ grows abundantly in clay, and contains according to Bley, sulphate of potash, and chloride of potassium. Plants characterize the particular kinds of soils in which they are found vegetating, but this, as we have before observed, does not depend solely on the mechanical or physical nature of the soil, but chiefly on its chemical constituents.

The presence of water and air in the soil is necessary for manifold and evident reasons. "All the *hydrogen* § necessary for the formation of an organic compound is supplied to a plant by the decomposition of water. The process of assimilation in its most simple form, consists in the extraction of hydrogen from water, and carbon from carbonic acid."|| The absolute necessity of water for the actual supply of food to the plant is evident; water is composed of oxygen and hydrogen, of which substances the latter forms a great part of the vegetable tissues; and not only does hydro-

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* (Lotus major.) This is a common plant in soils of this description; it flowers in July and August.

† Lotus corniculatus, the common bird's foot trefoil, is a very common plant, and flowers in July and August.

‡ (Saponária officinalis) is a plant from a foot to a foot and a half in height, with a stout cylindrical stem; it flowers in July and August.

§ All the hydrogen is not derived from water; some is obtained from ammonia.

|| Liebig.

gen exist as water in a plant, but as a member of its organization, when no water is present, that is, when it is dried. And this hydrogen is derived partly from the decomposition of water, partly from ammonia, which likewise contains hydrogen. The vegetable matter called humus, and formerly supposed to be the direct source of the carbon of plants, most probably has not the slightest influence in this respect.

Humus is the name applied indiscriminately to all the remains of decayed vegetables, and cannot directly, from its chemical properties, afford carbon to plants. It certainly exists in the soil, but does not on that account render it particularly fruitful; on the contrary, many soils very rich in this substance are poor as regards fertility. Humus is insoluble in water except when recently precipitated, and even then its solubility is very slight. The only uses of humus in the soil are the mechanical one of absorption, and the production of carbonic acid from it, by the action of water and the oxygen of atmospheric air.

It must also be very evident that humus, if it were necessary to the existence of plants, must have existed before plants were created, which is impossible, because humus is a product of vegetable decay. We must allow that carbonic acid is the chief, if not the only, means of supplying plants with carbon, and the absolute necessity of the presence of atmospheric air in the soil to adapt its carbon to the uses of the plant. All vegetable substances when moistened and exposed to the air, absorb from it oxygen. If a quantity of vegetable mould were enclosed in a bottle for some time, and the air in the bottle afterwards examined, it would be found to contain no longer oxygen, but on the contrary a portion of carbonic acid, equal in bulk to the oxygen previously contained in the air employed. If we mix this air contained in the bottle with atmospheric air in another bottle, containing a growing plant, exposed to the light of the sun, we should soon find that the carbonic acid would disappear, and the oxygen would be restored. Exactly the same phenomena transpire in the soil and atmosphere as in the bottle used for our experiment. The carbon in the vegetable remains in the soil, converts the oxygen in the atmospheric air contained in the soil, into carbonic acid, which is dissolved by the water always present, and thence received into the plant, not in this case by the leaves, but by the roots. This is one very important function performed by the air, when present in the soil; without air (oxygen) no putrefaction is capable of proceeding. And this principle is made use of practically in the preservation of many sorts of food for men and animals.* The combined presence of air and water in the soil, then, provides carbonic acid for the roots to absorb.

When the soil contains organic substances, having nitrogen as one of their component parts, ammonia is produced at the same time with carbonic acid. It has been alluded to that animal matters, which with the exception of fat all contain nitrogen, when exposed to the air in contact with lime are at last converted as far as their nitrogen is concerned into nitrates. When potash, soda, or lime is mixed with substances containing nitrogen, carbonic acid is formed and ammonia is liberated; for example, if we mix a quantity of blood with caustic, potash, and lime, and heat the mixture, carbonates of the two will be formed, and ammonia set free. But in the case of a substance in the soil putrefying, the carbonic acid formed combines or unites itself with the ammonia at the time of its formation. Any substance, we have before said, putrefying in the air, supposing nitrogen to form one of its component parts, yields ammonia. But in stating this it will be necessary to suggest that no alkali, no substance like soda, potash, or lime must be present; for if one or other of these bodies exist in the soil in which the body is putrefying, then instead of the formation of ammonia, a nitrate of one or other of these bases* will be formed,† particularly in tropical climates.

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* In putting potatoes, turnips, and mangel wurzel, into clamps we exclude the air of the atmosphere, and thus prevent decomposition; when turnips or any of the above roots are thus clamped, the portion of air contained in the interstices of the mass is converted into carbonic acid, and thus any progressive change or putrefaction prevented.

We have not hitherto mentioned the absolute necessity of oxygen in the *germination*‡ of a seed when placed in the ground, but air containing oxygen must be present. Many soils absorb with greater facility than others quantities of water, and the constituents of the air; and this depends not only on the mechanical but chemical § state of the soil. As regards the property of mechanically absorbing water, all soils in proportion to the quantity of clay which they contain, have the power of sucking in and retaining water :—while pure sand when exposed to the influence of a moist atmosphere would absorb nothing, a pure clay would gain very considerably in weight; and in all earths this property is in exact proportion to the quantity of aluminous or clayey material contained in them. All fertile soils possess the property of absorbing water and retaining it in an evident degree. The soil of a rich fertile piece of land was found to gain six times as much water as that from a barren heath.* In dry countries where rain is less frequent than in our own, this faculty of absorption is of even greater importance. But the use of water in the soil which we would here more particularly allude to, is that it is the means of presenting food in a soluble form to the roots of plants. All the chemical ingredients which are contained in the soil would be of no possible use to the plants, as it will be hereafter shown, that the pores or openings in their roots are so extremely small that they are not suited to receive any nourishment in a solid condition. The presence of water is therefore necessary to dissolve, and as it were digest the food which the soil contains. The absorption of water by soils from substances with which they are in contact is another most important consideration. The power of capillary attraction, assisted by evaporation from the surface, is a means by which nutritive properties of soils which they have lost, are restored. After a heavy fall of rain, or after continued falls, the substances in the soil even necessary to plants as actual food, which are soluble, are washed and dissolved out by the percolation of the water, and carried to the soil beneath the surface, below, in many instances, the reach of the roots. But when the soil of the surface again becomes dry by evaporation, a fresh supply of water rises again from below (on the same principle that the wick of a lamp draws up the oil) and returns again to the upper soil those substances, which the previous percolation had carried down ; and though this may, and does in some degree, return to the upper soil what has been carried down below, still much is lost by means of the drains and passages carrying away the soluble and most nutritious ingredients of the soil, and to this I would call the attention of farmers.

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* Those substances, like the ones mentioned in the text, which have the power of saturating acids, or depriving them of the properties which constitute them such, are called *bases*.

† This union of nitrogen with oxygen in the present case, does not, however, depend entirely on the action of the alkali present. The oxydation of the hydrogen contained in the matters decomposing, induces the same sort of motion in the atoms of the nitrogen, as is transpiring in the atoms of itself in the formation of water.—Colin and Liebig.

‡ The name *germination* is given to the process by which a seed commences to vegetate. The sprouting of barley, when it is malted, is the effect of germination. No seed can germinate without oxygen.

§ We allude to the fixation of ammonia by certain salts or acids in the soil, such as gypsum or any free acid.

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* Sir H. Davy.

Where a piece of good land has been drained at a considerable depth, the water which the pipes convey away must be thoroughly saturated with the saline and soluble nutritious ingredients of the soil through which it had passed. This water is for the most part allowed to run into the ditches unheeded, or if the fields border on the road, into it; accordingly the quantities of any fertilizing ingredient contained in the *washings*, or drainings of the soil, is wasted. In the manufactures, the so called mother liquors in many processes are to be again made use of for procuring still more of the substance contained in solution. So in our soil drainings, whether from top or bottom, we might so arrange that the water running from the soil could be allowed to stand in some pond or hole, when all that could be deposited there, might be again returned to the land as a restorer; any iron, which by this means might have been carried with the water would be no longer hurtful, as the salt of iron would by exposure to the air have become insoluble.

We have seen the absolute necessity of the presence of air and water in our soil, but we must guard against too great an excess of these two most powerful assistants. If we have a soil of a light and sandy texture, manure, which we put upon it, much sooner loses its properties than in a clay soil. In a clay soil, thick and stiff, the action of the manure is not brought out quickly enough.

We must have remarked in reading a paragraph a little way back that all the decompositions in the soil were owing to the presence of atmospheric air and water, assisted by heat; we can, therefore, easily account for the fact of manure exhausting itself in a soil too pervious and open to atmospheric influence. The manure in such a soil ferments or undergoes oxydation too rapidly, more so than the supply of food for the plants requires; the products also of the decomposition escape too readily into the air through the pores of the soil which are ever open. This does not refer only to a sandy soil, but to any soil which is too open and porous. Not only of the volatile constituents of nutrition is too light a soil a waster, but equally so of the fixed though soluble ingredients not less fertilizing. The percolation of the water more readily washes substances through such a medium, and thereby carries them to the subsoil, or into the drains, much loss being experienced by the plants. In a too light soil every thing should be done to obviate these faults which it possesses.

While on the one hand a sandy and very porous soil is objectionable for the above reasons as regards the action on it of air and water, so on the other hand land which is *too* clayey and stiff is equally disadvantageous, but from causes of an opposite description. In sandy and light porous soils, decomposition goes on with too much rapidity; in stiff and heavy clay lands the contrary is too much the case. When such soils are wet their close and tenacious texture prevents the admission of air, and when they are in the opposite condition their state of aggregation is so hard and impervious that they exclude it as effectually as a brick or a tile. The manure put into them does not decompose with sufficient readiness, owing to this exclusion of the air, or if decomposition takes place at all, the products of the action, from a paucity of oxygen gas, are not of a nature suited to the wants or capabilities of the plants. Though water does not readily soak into such soils, yet the power which they possess of retaining that fluid is very great; but organic substances may remain imbedded in them for long periods without undergoing that perfect decomposition which alone is capable of producing, from organised matter, the simple compounds which constitute the food of plants. This kind of soil possesses these properties in excess which were so deficient in the sandy one, and the means of improvement are obvious. "If we perfectly drain thin clay soil by furrow and draining," says Morton, "and deepen the subsoil with the spade or the subsoil plough, making it pervious to the moisture which falls upon it, that it may immediately sink to a depth below the reach of the roots of the plants, the cultivated surface will be dry; *and if we reduce the tenacity of the soil by applying to it those light or sandy substances*, which, when well incorporated with it, will make and keep the soil permanently porous and friable, then the land which before produced only a poor crop of carnation grass, or if arable of oats, will now produce an abundant crop of wheat, beans, oats, clover, and even turnips; and if properly laid down, and full of manure, will form a rich pasturage for any kind of stock." In all the manures applied to such land as this, it should be the object of the farmer to consider as much as possible its state of aggregation, and to apply to the sandy soil such heavy and adhesive matter as the bottoms of dikes and ponds mixed with the dung of his yard; and for the strong and adhesive ground to make use of manures in such a state that the porosity of the soil be increased by their addition, as light straw dung, dung mixed with peaty soil, and any thing of a similar nature suited to the purpose. The plan of burning very cohesive lands is likewise a method much to be praised.

Chalk * as regards its adhesiveness and compactness when wet, or hardness when dry, is intermediate between clay and sand, conferring friability and the capability of being easily worked on a heavy tenacious soil, and rendering more firm and compact the soil whose porosity and want of tenacity are caused by an excess of sand; and the same remark may apply to magnesia.

We have yet in our sketch of these mechanical properties of soils to notice the action of other most important and invisible agents; the effects of heat and cold we know in their general bearings, that of the former being stimulating and exciting, causing an increase of action, while the properties of the latter are the reverse. We have said that it is only on the large scale by cultivation and proper draining that we are able to modify the temperature of our atmosphere, but owing to certain properties of matter in a solid form we can alter the relations of our soils to heat and its effects. This power which we have, depends on several laws; the laws of radiation, of which we spoke so lately when mentioning the formation of dew; the laws of conduction, one body having the property of allowing heat to pass more rapidly through its substance than another. If we put into a fire a piece of wood, we can hold it in our fingers without burning ourselves, till it is nearly consumed; but if we hold a

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* Carbonate of Lime.

piece of iron of the same length, we shall soon discover that the heat travels more quickly into our fingers. Iron then on this account is called a good conductor, and wood a bad one of heat, or as it is called when considered as a body with recognisable properties, *caloric.* Glass is a bad conductor, and we often find this to our cost on pouring a hot fluid into a thick bottomed tumbler; this depends on the glass being a bad conductor, and on another property of heat, that of causing bodies to expand; when that part of the glass on which the hot water falls becomes heated it expands more than that part which is not in contact with the heating fluid, and in expanding, as it cannot do so uniformly, it breaks; a thin glass would not do so, and it is easy so see on what account. The power of absorbing heat is also one which all bodies possess, and the reverse, the powers of reflecting and transmitting heat. The ways of these various powers or properties of matter are more readily shown by illustration, and when we have by this means acquired a general outline, we shall see in which of their bearings they influence our land and its cultivation. If the sun be shining powerfully, and we allow the rays to fall on a piece of cast iron, we shall find that the air remains comparatively cold while the iron has become warm; yet the heat of the sun had passed through the air without warming it. If the iron be painted black it would get hotter sooner than if it were painted white. The air in this case may illustrate the invisible atmosphere of our earth, and the piece of iron the earth or soil. The earth on a warm summer day is always hotter than the air, and the air is never warm except by the influence of the earth. Some bodies cool sooner than others after having been heated, and this depends on the different force of the radiating power.

Sandy soils of a dark colour become hot sooner than those whose colour is light, and though not to a very great extent, still to an amount worthy of consideration. A sandy soil takes much longer to cool than one of clay, or of peat. And though this is perhaps in itself a benefit, it is counterbalanced by disadvantages; if a sandy soil parts less readily with its heat, so does it in inverse proportion permit the deposition of dew, and the heat which it would absorb, would in conjunction with the air and moisture so hasten the fermentation of the soil or manures in the soil, that they would soon become exhausted. No advice can here be given, if the farmer find his lands destroy as it were his manure or waste it, we have explained many causes which would lead to such results; if on the contrary his land is impervious to the air, and to the action of heat, by admixtures of substances of the reverse nature, he may find a remedy.

Sandy soils retain heat, or remain longer hot, than clayey ones; clayey, than peaty.

Is the heat of the sun the cause of other sources of heat, when its action is combined with those of air and water? We should answer, yes. Has the fermenting matter in the soil any relation to the actual temperature which it possesses as a producer as well as an effect of heat? This latter question we are disposed to answer likewise in the affirmative. If a certain degree of heat is necessary to commence fermentation, this heat increases as fermentation proceeds within certain limits. In the soil likewise fermentation originally induced by heat is now the supporter of a certain temperature. The conversion, by the action of oxygen, of carbon into carbonic acid, and hydrogen into water, is always attended with an increase of temperature.* A piece of coal left to undergo decay, or in other words slow combustion, would produce the same quantity of heat as if it were burned in a fire.† On the same principle that a dunghill heats and rises much in temperature, by the slow combustion of hydrogen and carbon, does the same process once commenced in the soil produce quantities of heat in proportion as regards the rapidity of their development, to the rapidity of the combustion or oxydation of the organic matter in the soil.

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* The chemical changes of bodies are productive of equal *quantities* of heat, whether these changes progress rapidly or

Of the effects of heat on vegetables we are aware from our general observance of what is going on around

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slowly. If we mix water and oil of vitriol the same quantity of heat will be produced if we mix the two fluids suddenly or by degrees; in the former case the heat is developed rapidly, in the latter slowly. If we burn a pound of starch or flour in the air, and by that means convert it into carbonic acid and water, we produce the same quantity of heat and no more than if we had eaten this pound of starch or flour, thus by respiration converting its carbon in our lungs or bodies into carbonic acid. Combustion in our atmosphere is the union of bodies with oxygen, and whether this process is rapid or slow the same quantity of heat is generated, and the only difference is that in the slow process more time is allowed for the conduction and diffusion of the heat produced.

† Many plants and the flowers of most give out carbonic acid to the air, and it appears that this production of carbonic acid is actually a source of warmth to the plant itself. The subject has been one on which much evidence has been produced, but the experiments of Dutrechet have proved beyond a doubt that plants have a means of maintaining a considerable degree of warmth, by the slow combustion or oxydation of carbon and hydrogen (coal gas is carbon and hydrogen) and in proportion to the quantity of carbonic acid generated, was the temperature high or low. At night in the absence of the sun, when more carbonic acid is disengaged, the quantity of heat would be greater, and thus the absence of the sun's heat would in some degree be compensated for by the functions of the plants themselves.

us, and if we state that above or below certain temperature our plants cannot vegetate, it will be sufficient, premising that within certain limits vegetation increases with the temperature.* As regards soils, then, we find those of a sandy open nature have ever a tendency to promote the changes of substances, for they have more porosity, and allow more freely the entrance of air; from the same reason they do not prevent the rapid departure of the gaseous nutritious matter generated; they allow the water to pass freely through them, and by that means suffer loss in their soluble ingredients; and lastly they absorb heat more readily than other soils, and thus urge on decay and fermentation, while they part less rapidly with the heat they may have gained during the day, and prevent the deposition of dew.

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* We shall treat more fully on the effects of heat in that place where the functions of the leaves and other parts of plants come under our especial notice; but man and plants are subject to the laws of matter, and evaporation proceeds rapidly from the skin of a man, the leaves of a plant, or from the earth. The fluids which evaporate from the body are restored by drinking, the water exhaled from the leaves of a plant is derived from the soil by the roots and from the air by the leaves, while the soil is re-supplied with its watery treasure by a part of the same mechanism. The sun shining in a hot summer day very powerfully on the land, were it not for this evaporating power, would render it so hot as to be intolerable, but water requires to contain more heat when it is in the state of vapour than when in the fluid form, and by this means the temperature of the surface of the soil is prevented from becoming too great. Evaporation of water is used in tropical climates as a means of cooling wine and other kinds of drink, and by the evaporation of very volatile fluids, such as ether for example, such a degree of cold can be produced as to freeze water. Evaporation of water requires heat, and water in the form of steam or vapour may be considered as a sort of union of itself with heat; the condensation of watery vapour again gives off the heat which it contained when in the gaseous form. If a jet of steam were passed into a pail of cold water, the water would continue to grow hot till of the same heat as the steam (212° F) when it would begin to boil, and the same quantity of heat as would be conveyed into it by the steam would escape in the same form.

If vegetation is more rapid in summer the supply of food is in every way more abundant. The decomposition of matter in the soil furnishes the supply necessary for the more rapid growth of the plant. Every phenomenon which we even slightly examine tells us still more of the beautiful means provided for what appear the simplest ends.

Each kind of soil is an antidote for the faults of the other, the sandy soil possessing in excess those properties deficient in those of a too tenacious and clayey texture. We can therefore easily regulate our means to the supply of our several wants.

The use of saltpetre and other compounds of nitric acid,[*] and the benefit derived from them as manures, is generally well known among farmers, and from this we shall not be surprised if we find such substances continually being formed on the earth by the combined agencies of heat, electricity, the porosity of the soil, and oxydation. We know that saltpetre is very frequently formed in those situations where animal matter is decaying in contact with lime and similar substances,* and that in old stable walls and situations of like nature, exudations of nitre are often the result of the oxydation of ammonia which is generated.

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[*] Nitric acid is the common *aqua fortis* of the shops; it is a most powerful acid, and is composed of five atoms or combining parts of oxygen united to two of nitrogen; when it is united and neutralised with potash it forms *nitre* or *saltpetre*, the nitrate of potash of chemists. When in the place of potash there is soda in union with the acid, a nitrate of soda is produced, such as is now imported under that name from Peru and Chili. When nitric acid is combined with ammonia, the salt is termed nitrate of ammonia, which as will be seen is formed in the atmosphere during thunderstorms, and is found in the rain.

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* In the manufacture of saltpetre by this means, all animal and vegetable matters containing nitrogen can be used with advantage; wormwood, thistles, cabbage stalks, &c., are mixed in holes with cut straw, and all sorts of dung and earths which contain organic matter; to this mixture are added the runnings and cleaning of all sorts of houses or sheds where animals are kept; urine also and the offal from all sorts of animals; this compound mass is mixed again intimately with lime remains from the kilns, with old mortar, with the ashes of the soap boiler after they have been exhausted, with chalk and with marl; in fact with any substance likely to contain lime, potash, or soda.

The composition thus made is formed into heaps from six to eight feet in height, and of a pyramidal shape, either in the open air *(nitrières à l'air libre)* on firm floors of hard clay to prevent the absorption of the fluids of the mass; or under the cover of sheds to protect them from the unlimited effect of the weather; the lower part of the heap on the windy side is protected by mats of straw, to prevent at once the effect of cold and evaporation *(nitrières couvertes.)* On every farm in Sweden this process for the preparation of nitre is put in practice, boxes being substituted for the heaps.

The heaps must be kept *warm and moist, and free access must be permitted for the atmospheric air;* and the heaps are frequently wetted with spring water, exhausted potash liquor, and urine, so that a moisture like that of good garden earth may be maintained The formation of saltpetre is more rapid in *summer* than in *winter.* To allow the free access of air the heaps are perforated with holes and layers of fagots are placed between the strata of which the heaps are formed; and the heaps are turned over every year that the greatest possible access may be permitted for the air. The heaps are allowed to remain three or four years, and when about one cubic foot of the earth at the surface yields about one pound of nitric acid salts, they are considered fit to be lixiviated or washed out. The salts in such a heap are of course various in their nature, the predominating ingredient being nitrate of lime.

Schubarth's Handbuch der technischen Chemie 3te Ausgabe Erster Band. S. 309.

Nitric acid is found in combination with soda in Peru and Chili, and in such large quantities that it is imported into this country for the manufacture of sulphuric and nitric acids. In India nitrate of potash is likewise found in the soil at the surface of the ground, and sufficiently abundant to furnish Europe with enough for the purposes of manufacture and commerce. It is chiefly, but not entirely, in tropical countries where saltpetre is found to have been formed in the greatest quantities, but there are situations in many parts of Europe and North America, where its presence in large proportions has been detected, for instance near Hamburg, in Germany, in Apulia, on the Adriatic sea, and in Spain, Poland, and Sicily. That the greater abundance, however, of salts nitric acid in tropical countries depends on the temperature and more rapid decay of animal and vegetable substances, and the effects of electricity in the frequent recurring thunderstorms, there is little reason to doubt.

It has been found by chemists that many substances by their process of oxydation produce ammonia, or induce, during the action which they themselves are undergoing, the elements of ammonia to combine in that form. The rust of iron is found frequently to contain ammonia, and many minerals also contain it. It is likewise frequently a result in chemical processes of oxydation. All this shows us the great benefit of the presence of air and water in the soil, and some also of late years have given it as their opinion, that matter containing nitrogen, during the process of being converted into nitric acid, induces a similar action of oxydation in the nitrogen of the air. We have before alluded to the formation of saltpetre, and other compounds of nitric acid in various parts of the earth, and regarding their artificial formation it has been remarked, that in the artificial heaps of animal and vegetable matters, mixed with lime and other alkaline bodies, more nitrogen was contained in the nitric acid salts formed, than existed in the matters of the heap, and thence the conclusion drawn that the nitric acid was formed at the expense of the air of the atmosphere.* In secondary lime stone and other rocks in which exist animal remains, saltpetre is found exuding or efflorescing; but in these minerals it does not exist below a certain depth, so deep only as the air and water could penetrate. Perfectly dense lime-stone, such as marble, was not found to contain any saltpetre.

Fontinelle, in some experiments, has shown the quantity of nitre produced by the exposure of various mixtures for the same weight, and for similar periods of time, to the atmosphere in a covered shed, and his results would lead to the supposition that no nitrate is formed unless organic matter be present.† Whether the opinion of J. Davy and Lonchamps is correct we shall not here decide, our point for consideration is the necessity of air in the soil, and the effects which it produces. There is no doubt that the nitrogen of a soil when it exists in some one or other of its forms,

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[*] This opinion has no foundation in experiment, and in the latest and most accurate investigations on nitrification by Kuhlman, he did not succeed in causing the union of nitrogen with oxygen by means of spongy platinum, though ammonia united forming nitric acid; at the same time he found that all volatile compounds of nitrogen, including the vapour of nitric acid, were reduced by hydrogen and the carbo-hydrogen ammonia being formed.

It is not improbable that nitric acid is so far reduced in the plant, its oxygen going to the air, and its nitrogen, after the intermediate step of ammonia, to the organs of the plant.

[†] Fontinelle exposed in a shed, in wooden tubs for three years, the following mixtures, with a view to ascertain if nitre or saltpetre were formed, and in what proportions.

not suited to the nourishment of plants, is rendered nutritious either by being converted into ammonia by the combined action of air and water, or into nitric acid, by the influence of the oxydation of other matter, and the presence of alkaline substances.

In the table in the note from Fontinelle, we see the relative quantities of saltpetre formed in different composts or mixtures.

If the opinion, that decomposing animal or vegetable matter containing nitrogen is capable of inducing an oxydation of the nitrogen of the atmosphere is correct, then by permitting the entrance of air into the soil and manure heaps, we render this nitrogen available for vegetable nutrition. There can be no doubt, however, that ammonia is in many cases of oxydation produced

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The quantities of the soils and mixtures exposed were as follows:—

43 lbs. 12 oz. av. of unwashed calcareous sand, moistened with distilled water, contained traces of saltpetre.

43 lbs. 12 oz.		of granite powder, the same traces.		
—		of washed calcareous sand, no trace.		
—		of ——— granite powder, no trace.		
—		of calcareous sand	0.004	saltpetre.
—		of granite powder, moistened with spring water		
—		of clayey earth	0.016	—
	arable soil		0.030	—
—	—	with 1-5 good lime rubbish	0.038	—
—	—	1-10 sheep dung	0.056	—
—	—	1-10 horse dung	0.048	—
—	—	1-10 mixed animal dung	0.060	—
—	—	1-10 cow dung	0.044	—
—	—	1-10 vegetable manure.	0.040	—
—	—	1-10 meadow soil	0.050	—
—	—	1-10 animal and vegetable manure, mixed with 1-5 good lime rubbish	0.080	—
—	—	1-10 blood	0.048	—

Dingler's Polytechniches Journal (bd. 13, s. 343.)

by the union of one of the elements of the water, hydrogen, with the nitrogen of the air, carbonic acid being generated at the same moment through the agency of the oxygen of the air, and that liberated by the decomposition of water.*

Having hinted at the probability of electricity being one of the disposing causes of the formation of nitric acid and its salts, it will be well to explain some of the phenomena of this very powerful and universal agent. Electricity is so called from a Greek word, signifying amber,† (ηλεκτρον) because amber is easily excited to an

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[*] In chemical investigations a peculiar series of facts has come to light as regards the tendency of certain mechanical forms of matter, to induce the combination of different substances. There must have been remarked by many, a peculiar sort of lamp, by which, when a stream of gas is allowed to escape on to a small piece of metal, fire is produced. The piece of metal is platinum, which from its properties of unchangeability is classed amongst those termed noble, and is so mechanically divided as to be in a very porous condition; the gas which jets out on this piece of spongy platinum is hydrogen, and is produced by a process unnecessary to describe. In coming into contact with the piece of spongy metal the hydrogen enters its pores, and combining with oxygen to form water, generates so much heat that it takes fire. This metal induces many other transformations and decompositions, such as that of spirit of wine being converted into vinegar, not only when in this spongy or minutely divided state, but also when in the form of a clean polished plate. Some other metals possess also this property, and certain chemists have supposed that in the soil the same sort of action to a certain extent is caused by its porosity, aided by the action of matter undergoing a similar change to those of which this supposed property of soils, and all porous substances, is considered a cause.

[†] When a piece of amber or sealing wax is rubbed quickly against the coat sleeve it becomes excited, and if brought near any light substances, such as feathers and small pieces of paper, they will be found to cling and adhere to the wax or amber, though these substances would not produce this effect had they not been excited by friction.

electrical condition. Nothing is positively known as to the nature of this substance or power, only made evident to our senses by its phenomena and effects in our earth. What its effects are on living beings in aiding their functions is likewise to us a matter of perfect obscurity, though from some few facts brought to light its influence seems to be important. The phenomenon of electricity most familiar to our senses from its frequent occurrence and amazing effects, is that of lightning. When two bodies contain unequal quantities of electricity, the one containing the less proportion is said to be negatively electric or excited, while that which contains the larger proportion is termed positively excited. When two bodies are in these conditions, and they are made to approach each other, sparks of fire pass from one to the other until an equilibrium in their electric conditions is produced. In the case of a thunderstorm, the clouds which are in a highly electric condition, when they come into proximity with each other or with the earth discharge their excess, and with such violence and brilliancy as to cause all the beautiful, useful, and dreadful effects of lightning, the explosion of which is echoed and re-echoed from side to side, and from mountain to mountain, causing the rolling and tremendous sound of thunder. Electricity is produced on the earth by many, almost all the changes of condition in the substances which there exist; the evaporation of water, more particularly of the sea, produces and carries away to the clouds positive electricity; the decomposition of matters in the soil, the combustion of all bodies, such as wood and coal, give off vapours and gases which are positively electric and are carried to the higher regions of the atmosphere.

The rain which falls during a thunderstorm has been found to contain a salt of ammonia, a compound of this body with nitric acid; and this circumstance, namely, the formation of nitric acid (ammonia always exists in the air) has been explained and shown to be the effect of electric discharges.

Cavendish, a great chemist of this country, first showed that nitric acid was formed by passing sparks of electricity through a mixture of nitrogen and oxygen gases. The quantity however was very small, so very small that little influence can occur from its production by lightning in the air. But since the time of Cavendish it has been shown that, when electric discharges are made in an atmosphere containing ammonia and oxygen like the atmosphere, a salt of nitric acid is formed at the expense of part of the ammonia and the oxygen of the air, and this salt (nitrate of ammonia) has been detected, and is probably always present in the rain of thunderstorms. In tropical climates the nitrates are most abundant, the continued decomposition and rapid putrefaction of all animal matter, assisted by the almost uninterrupted discharge of electric fluid, are doubtless some of the causes of their abundance.

More frequent electric discharges and more rapid putrefaction are always present in summer than in winter, and more ammonia is carried into the air by the latter process, to be converted into a fixed and permanent salt by the former. Plants, it has been supposed, have greater capabilities for assimilating the nitrogen which is given them in the form of nitric acid in hot weather than in cold, and besides this, much of the ammonia would be, for the time, lost to vegetation, were not some means provided for rapidly returning it to the soil. In the tropics where evaporation and decomposition caused by the heat are more rapid, and thunderstorms are more frequent, most probably those thunderstorms so beneficial to vegetation are caused by the very processes whose deleterious effects they so parry and alleviate, for we have mentioned that evaporation and putrefaction were causes of electricity.

In those conditions of the atmosphere commonly known as electric, or more commonly by the qualification of *feeling like thunder*, the rapid growth of vegetables is most remarkable. On one occasion a young stalk of barley during three days of this electric weather was observed to have grown six inches, and a shoot of a vine had actually increased two feet in length (Duhamel.)

The condition of plants and the rapidity of their growth seem to be causes as well as effects of electricity. The quiet meadows and woods in a midsummer's day exhale the materials of the ensuing thunderstorm, the very breath of our bodies and the odour of flowers convey aloft the force about to be discharged over the earth with such magnificence. The silent evaporation from all things on the surface of the earth, though unobserved and unheeded, is one of the great and continued means which supply the electricity of this artillery of heaven. Thunder storms are more frequent in those climates where vegetation is more luxuriant, and the very luxuriance of this vegetation, by the discharges of electricity which it occasions, supplies to itself the nutriment which is showered down by the rain in the form of nitrate of ammonia; in this country likewise in summer, the very beauty of the green wood and the perfume of the meadows, the lucid vapours of the running streams and the still lakes, seem by their delicious fragrance and cooling evaporation to solicit for the supply of fresh stores which are soon bestowed on them by such ministering agents as the thunder cloud and the lightning flash.

Of the more direct applications of the electric force to the purposes of vegetation little is known, plants have been found to vegetate more freely in water which contained an excess of electricity, or was positively electric, than under ordinary conditions, and some have been speculative enough to recommend the erection of immense machines to be turned by wind for the purpose of exciting the plants to growth; such projects as these almost excite a smile when we discuss them.

Of the mighty power of the electric fluid we have almost daily proof in the destruction it causes, but the great benefits which we derive from it are only to be seen to their full extent by the careful observer of the intricacies of the creation; the time perhaps is not far distant when steam will be put aside as a moving power, and electricity substituted.

We have only now in the present place to speak cursorily of the general nature and effect on vegetation of another of these imponderable though powerful agents. Light, without which all the beauties of our world would be as nought, is no less necessary to plants than it is delightful and indispensable to man. Many of the changes in organic matter are owing to the chemical powers of the component parts of light. We are conversant with many of the properties and phenomena of light, and the important place which it holds in retarding by its absence or hastening by its presence, decomposition or reunion of the elements of our bodies and those of plants, renders the study of its properties most interesting.

The light of the sun contains certain rays called chemical, which are more or less intense in their action, and certain others which are the cause of color in all that we behold; the same power which builds the rainbow in the sky and decks with varied color the soap bubbles of the schoolboy, supplies the leaf of a plant with power to obtain its food, and the mind of man to behold with gratitude the goodness of his creator, and with wonder the magnificence of his works.

When we speak of the leaves we shall find that without light they cannot perform the functions for which they exist—they cannot, unless in the light of the sun, decompose the carbonic acid of the atmosphere. Without light plants cannot flourish; they become pale and sickly, growing into long and straggling shapes in the attempts made by some directing influence to urge them to the presence of an agent so important. Plants growing without light become altered in their component parts;* there is a deficiency of organic matter in all their tissues, and a disorganization of all their functions. Substances are produced not of a normal nature, and those so necessary for their well being and beauty are left unformed. Cover a plant up from the light, it will lose its green colour and the grace and beauty of its form; and leave but the slightest aperture through which one ray of the desired light can pass, and to it you will perceive the energies of the plant will be directed. When the sun shines all vegetation

* This is the case more particularly with those vegetables of the most perfect organization; plants of a lower order in many instances require less the aid of light in performing their functions. Many lichens, mosses, and fungi (mushrooms, etc.) flourish best in situations only moderately exposed to light; many plants were found growing in the subterranean galleries of mines (Humboldt), and moss is found adhering to those places not exposed to the sun. The American Indians are accustomed to guide themselves by the aid of this circumstance, the north side of trees being invariably more covered by moss than the south.

is of a darker and more healthy hue than under the shade of woods or trees or hedges, and not only greener and stronger but better able to supply, for the wants of increase, the elements of its formation.

When potatoes sprout in a cellar, and thus in the absence of light there is produced a body called *solanina* of a very poisonous nature, whilst the green matter of the leaves which contains hydrogen and carbon is not formed at all. Plants which are white from being kept from the presence of light are said to be etiolated, from the French word *étoile*, a star, from some fanciful idea of the whiteness being produced by starlight. The compounds of hydrogen and carbon are found to be absent in a great extent in etiolated plants. Woody fibre is signally wanting, and those volatile and odoriferous substances which characterise some species are also to a great extent absent. In the common cabbage the interior leaves which are covered up from the light are white and less strong in smell and taste than the external covering. The same is the case with the common lettuce and endive, and celery unless it were preserved from the light would be uneatable from the quantity of volatile oil (carbon and hydrogen) and woody fibre which it would contain.

The necessity of light for the growth of plants is shown on all sides of us ; if we walk in our gardens, we see all the leaves of the wall-trees turned round to the sun ; in our rooms how anxiously the plants there preserved shoot forth their branches in that direction from whence the light is derived ; a field of corn, when ripe and fit to be cut, we find always inclined towards the south, and a familiar example is the sunflower,* ever turning itself to the source of light.

* The sunflower contains nitrate of potash and ever turns itself to the influence of the rays of the sun. May not light have a much greater effect in inducing decomposition of oxygenized bodies in

The corn under trees in our fields is long and weak in colour and substance, and we may observe that even the weeds in the hedges grow sickly and tender in the absence of the sun's reviving light. In the absence of light the flowers close up the treasures of their blossoms, and many plants fold their leaves carefully through the night, nor open them till, by the reviving influence of the sun, they are again made to supply the wants of their tissues from the surrounding air.

Plants should be all freely open to the light of the sun ; without it they cannot luxuriate, the air is of no service to them, and its nutritious parts are useless unless their organs receive the all powerful influence of the light of day. We must expose to the direct power of the sun all the plants which we have removed from the pure guidance of nature, that they may still be able to assimilate food, and organize the products for which we watch with such care, and which we collect with such labor. For the more, be it understood, plants are exposed to the light, the greater is their power of obtaining from the air, what is in it provided, and which they require. But we must allude to one instance where the presence of light is said to be injurious; when seeds are placed in the ground to enable them to germinate, they require the assistance of air, water, and a certain degree of warmth, but the presence of light is injurious.* Whether or not light retards the

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plants than we have hitherto supposed? May not the bright or dull state of the season have much influence on the effect of the nitrates as manure? Does not the unvarying benefit derived from these salts in the tropics add weight to the probability of the supposition?

[*] The experiments of Ingenhouse† first drew the attention of physiologists to this fact; he found that seeds exposed to the light did not germinate so freely as when they were protected from its

[†] Exper. sur les Veget. t. II.

progress of vegetation, it is the usual practice in planting a seed to place it slightly below the surface where it may be guarded from birds (and from any deleterious effect of light) while it can receive the necessary supplies of water, air, and warmth.

The roots of most plants also are required to be concealed from the light, and there is not the least doubt that by the action of light, a plant about to grow is predisposed as to the direction to be taken by the fibres and sprouts as they are formed. Some seeds were made to grow in such a situation where the only light they possessed was admitted from below, and the result was that the leaves and branches grew downwards towards the light, and the roots took an ascending direction. This is, however, not the case with all plants, some tribes receiving all their support by roots (and other organs) exposed to the air and light without connexion with the earth.

Having endeavoured to give a general account of the various phenomena connected with the media in which animals and plants exist, we must leave their more full discussion till we treat of them in junction with partial applications of the laws of nature, over which man has by knowledge to some extent obtained a discretionary power. It will have been seen in how many instances we may assist or retard, by artificial means, the progress of the changes of matter, by bringing to our aid the natural opposing causes with which we are acquainted.

influence. Sennebier‡ repeated his experiments with the same results, and found the conclusions in every case to be correct. The truth, however, of these results was denied and again confirmed by the repetition of the experiments. Saussure,‖ however, was of opinion that it is the heat and not the light which exercises a retarding influence in germination.

‡ Memoires Phy. Chim. t. III. ‖ Recherches Chimique sur la Vegetation.

CHAPTER III.

THE MEANS BY WHICH PLANTS OBTAIN NOURISHMENT FROM THE AIR AND SOIL—THE FUNCTIONS OF THE VARIOUS ORGANS.

Plants, unlike animals, are fixed to one spot, and from the matter which surrounds them they must gain their nourishment or die; nor have they, like animals, that discretionary power to choose between what would be injurious or beneficial, to the same extent; but to compensate for this, they are so surrounded with subservient agents, and so provided with mechanical means within themselves, that the vital processes are performed without any effort being required on their part.

A plant in all the stages of its growth bears great analogy to the *fœtus* or unborn offspring of an animal. *Its* food is conveyed to it by a circulating fluid not its own; the water and salts in the soil, and the gases of the atmosphere, supply the plant with food as long as they contain it, and fresh stores are ever being provided, and circulated by great and never failing means. When the young animal is born however the similitude ceases. It has the power of locomotion, and is endowed with sensations prompting it to provide for the uses of its body. The sensation of thirst would induce it to search for some fluid to alleviate it, or hunger would tempt it to *seek* and devour food. Plants have not this power, nor the advantages of sensation, but the mechanical laws of matter, assisted by chemical changes, are sufficient to compensate for the deficiency. The evaporation of water from the leaves of a plant would be prevented from exhausting the stores by the supply of the roots, and the remedy in this case is so suited to the circumstance, that in proportion as the necessity is great, the supply is abundant.

We will trace from their commencement the phenomena of the existence of a plant; from the time when as a seed it was placed in the ground, through all the stages of its useful being, till by the modification of its food it has completed itself and produced germs like the one from which it sprung, again to be the axes for new revolutions, and again to produce new stores of organised matter, like itself.

What however must we endeavour to explain before we commence our journey through the winding paths from an acorn to an oak? Let us just think a moment how it is, that two seeds of almost identical form and composition should produce plants so totally different from each other; a chesnut or an acorn and a garden bean, where can one perceive, in regarding these, any indications of their future forms? The wheat seed, the grain of barley and of oats, in their composition and their outward form, do they present one salient angle of dissimilitude for speculation to fix its theories? They do differ certainly, but how strangely more perceptible are the differences when they have grown and come to maturity.

Yet every plant has its seed, which alone can produce such an one as that from which it sprung, as any animal can alone produce beings like itself; some suppose that organised beings can be produced from new combinations of matter, and that, for instance, mites could be formed by the decay of cheese, or maggots by putrid flesh; or that plants were produced by certain soils. All organised beings spring from certain germs or seeds produced by beings like themselves, and from these germs alone can such beings be produced. The seed of a plant is the commencement of a certain arrangement of matter induced by a certain power of which we are ignorant, but which, to conceal this ignorance, or to give us some means of being understood when we speak of it, has been called the "vital power." This vital power, then, exists in the seeds or germs of plants and animals; but it is only under certain concurring circumstances that its force can be brought into action. A seed of a plant may have been buried deep in the soil, very deep, far below the influence of light, air, and warmth, and there it would remain till some accidental cause might bring it into the presence of agents necessary for its development. The germ of an animal, the eggs of the common blue fly for instance, are deposited after the female has undergone impregnation in a situation suited as well to the development of the young animal as to its support when endowed with active vitality. Hosts have endeavoured to prove the spontaneous formation of highly organised beings. Virgil supposed that bees sucked their young from the blossoms of certain flowers.

"Verùm ipsæ e foliis natos et suavibus herbis
"Ore legunt." *

Blight, the foggy close days of frequent occurrence in summer are supposed to bring, and the winds are said to carry in them the insect tribes that may about the same time desolate vegetation. We are so very ready to account for phenomena which are a little masked by some temporary difficulty, without looking closely at all the facts; the truth in such a case being that in the previous autumn, or in some time past, certain eggs of insects had been deposited, that they had been heated and cooled alike by the changes of summer

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* Georg. iiii. v. 200.

and winter, and happening to be subjected one day to a degree of warmth sufficient to induce animation, a drove of caterpillars was set free from the *ovæ* deposited some time before, which caterpillars were not perhaps immediately detected, because they were so small at first, that it would perhaps have been difficult to distinguish them had one sought. When ground has been newly turned up many weeds are seen to spring forth, and certain sorts of soils are supposed, very erroneously, to beget or generate certain species of weeds, the fact being that certain seeds had been buried by some accident below the influence of the atmosphere and of course remained inert, till by exposure they germinated and produced similar plants to those from which they were produced. Seeds of plants may remain for ages in positions unsuited to vegetation, and yet when brought within the influence of the proper exciting causes will be rendered capable of germination and reproduction. So long indeed can the seeds of plants retain their vitality that Professor Lindley has related that he has in his possession three raspberry plants raised in the gardens of the Horticultural Society, by seeds taken from the stomach of a man whose skeleton was found buried thirty feet below the surface of the earth, at the bottom of a barrow which was opened at Dorchester. He had been buried with some coins of the Emperor Adrian, and it is probable that the seeds were sixteen or seventeen hundred years old.

The smallest plant of the lowest order of organization has doubtless the same origin as those of a more perfect structure. The minutest moss and the largest forest tree alike spring from a germ produced by similarly constructed organizations. It is a too common error with many to suppose that, because our senses are not sufficiently acute to observe the minute intricacies of nature, they are not subject to the same laws and guidance of the same all-powerful mind; if our eyes could by some unusual accident be made a million times more powerful than now they are, we should be little disposed to doubt that the now invisible beings were as beautifully and perhaps more wonderfully imagined and created as to a Lilliputian would appear an elephant or a rhinoceros.

The creative power having at once formed an organised being endowed with powers of reproduction, is as regards its exercise confined to the being originally created. New organised beings, we believe, are not formed—the time of creation is passed; when the germ of any being or thing is once in existence, the process of its life for the future is simply development. Why should we suppose that a plant which is only comparatively small should be produced in a different manner from an oak tree which is in like manner comparatively small.

Let us then consider it decided that all plants are produced from seeds or germs originally provided by the first being of the species created. A fully formed seed * contains all the necessary machinery for the for-

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* A fully developed seed contains a small point called the *embryo;* and another part called the *cotyledon.* In some plants there is only one cotyledon, and these plants are called monocotyledonous, others have two and these are termed dicotyledonous. The cotyledons of the common bean are the two halves of its seed; the embryo is the little point which we may observe at that part of the seed where the kidney-like indentation exists. When the seed begins to grow, two shoots spring from this embryo, one called the *radicle,* which descends into the soil; the other called the *plumula,* which penetrates upwards into the air; the former is the commencement of the future root, the latter of the stem and branches. The starch which the cotyledons contain gradually is converted into sugar and disappears, going to supply nutrition to the plant, which when it is fully developed as regards leaves and roots, is left to its own resources.

mation of a plant; when it is therefore placed within the influence of certain exciting causes this machinery is put into action, various changes are gone through, and a young plant is at last formed totally independent in structure and properties, and capable of obtaining its nutrition from the air and the soil. A seed is a reservoir for the young plant, provided by the perfect organs of the parent, to supply food till such time as the development of the embryo is complete, when it will be able to obtain from the surrounding media the elements of its constitution. In a seed there are provided starch, gum, and a substance of a similar composition to the gluten of wheat, besides small quantities of inorganic materials. The starch in the seed and the gum, the former when it has undergone a certain change in condition dependent on a phenomenon which will be presently fully described, supply the embryo plant in the first stages of its remove from inactivity. To commence or assist these changes there is required the presence of those powerful agents, the invisible heat and atmospheric air, and a certain amount of water.* We will suppose now that we have put our seed into the ground, not too deep however, and that the ground is moist, and the air moderately warm; then are all the necessary precautions provided. The seed begins to swell and the chemical changes commence. Oxygen gas is absorbed from the air, and combines with some of the carbon of the seed, and in setting free carbonic acid, produces a certain degree of warmth. This induces other changes; the substance called albumen, resembling the gluten of wheat, is partly transformed into a body capable of changing the starch of the seed into sugar; we must see that some such change is necessary, for starch is insoluble, and could not circulate through the plant. The substance which is formed and possesses these properties is *diastase*,* which is always formed and found in germinating seeds. When the changes have progressed so far, a little sprout is sent out of the seed to form the future root, and another upwards to be henceforward the ground work of the leaves and branches. These are supplied and nourished by the reservoir in the seed, till they can get food for themselves, the sugar is circulated through their vessels, and the gum and other matters are conveyed away to give nourishment to the progressing organs. The root dives deeper into the soil; the leaf spreads out its tender hands; till both the one and the other are able, just in time, for their reservoir is empty, to gather food for themselves. How is it with a young infant? It could not digest beef steaks or roast mutton at the moment of its admission into life, so there is provided milk for it as food, in the breasts of its mother, which is just to the minutest atom suited for the purpose. Milk is just a solution of flesh and fat, already prepared to furnish the young with material for their growing parts. The mother secretes this fluid for her offspring, and a plant provides the nutritious parts of a seed for the same purpose. When the young gain strength, when their organs become deve-

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* A seed when placed in the ground sufficiently below the surface to exclude the light in some degree, and near enough to the air to be within its influence, commences to grow. It absorbs oxygen from the atmosphere, and gives out carbonic acid, and commences to progress through the stages of its being. It must be excluded from the light that no tendency to the decomposition of carbonic acid be induced by the chemical functions of the rays of light.

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* DIASTASE; this is a substance formed in the seeds of plants during germination, and has the peculiar property of converting starch into a substance called dextrine and finally into sugar. When barley is made to undergo the process of malting, the seeds on commencing to germinate produce a certain substance by the decomposition of the albumen contained in them, and this substance induces a change to proceed, that the starch contained in the barley is rendered soluble, and finally converted into sugar; to this sugar, barley, when malted, owes its sweet taste and its power of producing fermented or spirituous liquors. The process of malting is known to most persons; in it nature is imitated, and the seeds are placed in a situation where the necessary circumstances are present to induce the commencement of germination; when the process of malting is complete, when the starch is completely converted into sugar, the seeds are removed to a kiln and dried, so that their vitality be destroyed. When a plant germinates or sprouts in the soil the same changes take place, and when the process of germination is complete the leaves and roots of the plant are so far developed as to require no other supply of food than that which they derive from the soil and atmosphere.

Diastase may be separated from malt, and obtained in an isolated form by these means;—the malt is bruised with a small quantity of water, and the liquid pressed from it; to this liquid is added strong spirit of wine, which will precipitate all the albumen that may happen to be in the solution, and finally this solution is evaporated gently to dryness; impure diastase is the result.

This diastase is the first product of the decomposition of albumen or gluten, and is capable in this stage of its existence to induce what is termed the saccharine fermentation or the change of such bodies as are capable of such transformations into sugar. Diluted oil of vitriol (sulphuric acid) will convert the starch and woody fibre also of plants into sugar, in the same manner as diastase.

In the second *recognised* stage of the decomposition of gluten, yeast is formed, and this body induces another fermentation, the vinous fermentation; such as proceeds in all fermenting liquors, and is the cause of the conversion of sugar into spirit of wine; there is yet another change in the form of union of the elements of these bodies, and that is the formation of vinegar, a substance produced by what is called the acetous fermentation.

If we mix diastase prepared as stated above with starch, and keep the mixture at a certain temperature, one part of the former is sufficient to convert into sugar one thousand parts of the latter; if then we add to the sugar thus formed and in solution, yeast, it will be converted into alcohol or spirit of wine, and this again by further oxydation may be changed into vinegar.

loped (we speak of both plants and animals) they can find their food; can, to use the term generally, masticate and digest their food. The young animal would find the beef steak excellent, and the young plant would decompose the carbonic acid of the atmosphere and the ingredients of the soil, and flourish, increasing in bulk and strength. When those organs necessary for the vital processes are completed, the plant begins to form certain substances peculiar to itself, and to assume a form similar to its parent, to produce the same leaves, to require the same food, and finally to generate a seed or seeds like the one from which it arose itself.

But we must in passing through the phenomena notice some parts more particularly, for instance the roots which after a time gradually penetrate into the earth, seeking hither and thither those parts of the soil suited to their wants. The stem with its tubes and vessels to convey the nutrition from the roots upwards through all the parts of the plants. The leaves also which spread forth into the air, deriving from it so large a portion of the food of the tree on which they grow, and aiding as they do by the evaporation from their surface to draw up from below the juices prepared or obtained by the roots, to evaporate them to a proper consistence, and to modify or assist in their progress, the arrangement in the elements of the various substances produced by the different tribes of plants.

When the root of the seed which has been planted begins to increase in length it can insinuate itself into the most minute openings, and from the fact that all addition to its length is made by the deposition of new matter to its extremities, can so accommodate itself to the nature of the situation where accident may have directed it. We do not think that the roots of plants are endowed with instinct, that they can intuitively find out the situations where their food is to be found, wonderful indeed though the tales be that are related of such adventurous roots who travel on the bare faces of rocks for great distances in search of food.* But that they may be induced to take certain courses is probable enough, being led thus to do because in one direction the ground might be softer than in another, that certain mechanical obstructions had prevented their course in in one direction, so they were forced *mechanically* to go another. All this is natural enough—but not to suppose that the plants reason within themselves as to the direction in which they may send their roots. For it certainly is reasoning to say there is food in such a place, if I put out my root I can get it, and if I get it I can grow faster. I think we may safely consider that plants do not reason, and that they have not immortal souls (as some have actually stated themselves, and in modern times, to believe). The root of a plant is just a stem and branches which are prolonged into the earth, and which by a mechanical means may be made to change places with the latter. By gradually burying the top of a young plant and exposing the roots to the air, these latter will put out buds and leaves, and will begin to exercise the functions of the tree, while the top, which had been gradually buried, would send out little shoots and fibres like the roots, and in fact become a root.

The roots when they go down into the soil, begin to extract from it certain sorts of nourishment; we shall not enter into discussions whether they can absorb substances in a solid form (we should think not); whether their food be necessarily dissolved we do not think is a needful subject of argument here, as all must allow that if it be not in a state of solution it must be extremely divided; and solution is only a still further grade of division. Taking for granted that the extremities of roots are very fine in their structure, that the pores are most minute, we cannot go very far wrong in supposing that all food which they absorb must be in a liquid form, that is, in a state of solution. That roots absorb a great quantity of water we know, and that with this water they absorb considerable portions of inorganic matters of great insolubility, we are likewise sure. It may then be asked how comes this substance or that salt in the texture of the plant, each is quite insoluble, how could it enter the plant? Now no one would say that gold was soluble in water, nor is it; but, combine that gold with chlorine and it will then be soluble to any extent. Silica is found in almost all plants; yet it is perfectly insoluble in water; combine silica with potash or soda, and it will be rendered soluble, and thus may enter the roots and become part of the organization. Having decided that plants or their roots at least can only absorb substances in a state of very minute division—solution, let us enquire if they can select any substances from the soil likely to be beneficial to them, or reject any others whose properties might prove to be injurious. This is a subject of some practical importance, and we may examine a little what has been said and recorded concerning it.

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* See the *Gardeners' Magazine*, October 1, 1837.

Saussure* made solutions of many salts and other substances, and put into them to vegetate, plants of *Polygonum persicaria* and of *Bidens cannabina;* and what was the result? He found that the more hurtful the solution appeared to be the more of it was absorbed, and this he explains by supposing that these hurtful substances destroyed the extremities of the roots, and thus deprived them of their vital power.

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* Recherches, page 247.

He then made a mixed solution of various salts, and in it placed certain plants to vegetate with their roots entire; in this experiment he found that very different proportions of saline matter were absorbed. He then cut off the extremities of the roots, and found that the absorption had become indiscriminate.

Next, Daubeny made plants grow in a soil containing a certain substance which could easily be detected if it had been absorbed, and as from its having been supplied in a state of solution every facility was afforded, its presence would have been proved easily. But when the plants were analysed none of the said substance (nitrate of strontia) could be found in them. Now Sprengel when he analysed various kinds of fine seed corn always found the inorganic constituents to be the same; probably these specimens of corn were grown on different lands. The inorganic constituents of certain tribes of plants are almost invariably the same on whatever soil they may have grown.

Now there are some who reason thus:—We have planted seeds and watered them with a solution of arsenic or of blue vitriol (sulphate of copper), acetate of lead, and other substances, and the plants absorbed sufficient to kill them. Surely, say they, that if plants had the power of resisting the influx of such poisonous bodies they would have done so. This may be granted; but such a substance as sulphate of copper coming into contact with the delicate terminations of the roots, would, we should suppose, have a very similar action on them as it has on most other organic bodies; it would enter into combination with the matters of which they were composed, and positively destroy their texture. The delicate extremities of the roots would become eroded, and absorption would then progress mechanically. The same remarks may be applied to acetate of lead, and salts of a similar nature. Such substances as these are not likely to be found in the soil, and nature has not provided a means of resistance. We should surely never think of keeping a guard day and night at the doors of the Royal Exchange, or any other public place, to prevent the North American Indians from entering and scalping the people who were there met together.

If the roots do not find, however, a substance suited to the nature of the plant, any substance having a *certain* relation in common * may replace it.

We certainly think that plants can select substances from the soil, not from psychological, but chemical causes.†

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* The elementary bodies have been divided into certain groups from certain properties which they possess in common. Those substances which have the same crystalline form in combination are called *isomorphous*. Certain bases are isomorphous, and salts of these have been found to be able to replace each other in plants. What the cause of isomorphism is we do not know, nor why plants can only absorb isomorphous salts, but that the salts and earths found in vegetables are united *chemically* to the tissues I think there are good reasons for believing, more particularly as Daubeny finds the isomorphous bases replacing each other. Why should not the salts found in plants be in chemical union with the other parts?

† It is not wonderful to suppose that the mechanical construction of the root may, in union with any chemical power that it may possess, induce the absorption of certain salts in solution; how is it that alcohol will not dissolve the sulphates when other salts are so freely taken up by it, or why does it so easily dissolve the resins when water has on them no solvent effect. If we consider a varnish a chemical union of the spirit of wine with the resins, we may surely consider that there is some such connexion between the roots and the substances they contain. Plants contain ingredients always the same as regards their inorganic composition within certain limits, and we most surely may suppose that some power is

Some have asserted that plants get rid of the superabundance of some of their ingredients through the roots; that the roots have the power of excreting as well as absorbing certain substances. Still there is a certain doubt. We know that the leaves have the power of excreting certain substances, gases which they supply to the air, and most probably the roots have also. But this excretatory power of roots has been made to account for the benefit arising from the alternation of crops; whatever influence it may have in this respect many other causes tend to render this practice advantageous.

provided them in selecting their food, whether this is chemical attraction, or the effect of electric currency, or caused by the action of the bodies absorbed, in the roots themselves. How is it that when oats are sown on the same land as peas or tares, the former contain so large, the latter so small a quantity of silica? There can be no doubt but that plants do select certain ingredients which they require, and in different proportions, according to the species of the plant. Compare these two analyses of the plant of the common tare, and of the spurry (spergula arvensis).

One thousand pounds of each contained as under.

	Spergula	Tares (vicia sativa.)
Water (as water)	780 0	750 0
Nitrogen	4 0	4 3
Potash	9 3	3 4
Soda	4 3	0 3
Lime	2 6	4 0
Magnesia	1 5	0 8
Sulphuric acid	1 0	1 0
Phosphoric acid	1 5	3 0
Chlorine	0 5	0 5
Alumina, iron, manganese, and Silica	0 3	0 0
Carbon	110 0	126 0
Oxygen and Hydrogen	85 0	106 7
	1000 0 pounds	1000 0

Macaire-Princep of Geneva, endeavours to explain the necessity of the alternation of crops from certain substances which are excreted from the roots, and which, though these said matters be hurtful to plants of the same species, may be absorbed and become food for another tribe. He certainly proved beyond a doubt that plants excreted some extractive matter from their roots, and that the substance which came from plants of the pea tribe *(Leguminosæ)* gave to water a brown color; in this water thus impregnated with the excrementitious matter, he ascertained that plants of the same kind would not vegetate, but plants of another tribe did, such for instance as corn plants.

This experiment may prove in a manner beautiful in itself, how the quantity of humus may be increased in the soil by the growth of certain crops, and that the increase of humus or organic matter may be accounted for in meadows or lands long laid down to pasture, but that the excrements of one tribe of plants are beneficial to another, they do not substantiate. Liebig remarks,—"How should the excrements of one plant become food for another—there is no analogy for this? And why is fallow useful when it is kept free from weeds? It allows time for the decay and decomposition of the excrements of an organic nature that may have been deposited by the preceding crop." We may explain how the rotation of crops is beneficial on other grounds, and we certainly do not believe that the extractive matter so given off by roots, can, in that condition, become food for other plants.

As regards its hurtfulness, it is probable that it does not act beneficially on the same crop; and for any other, should be speedily destroyed, or converted into humus, or vegetable mould, by the application of lime and alkalies.

The decay of the excreted organic matter, when the land is well cultivated, is rapid, and it cannot therefore be seriously detrimental to the crop about to follow; the excrements from a crop of potatoes have no prejudicial effect on a crop of rye, which may succeed them,* that is to say, they are decomposed so rapidly that time is not allowed for them to be injurious. But besides this extractive matter, it is very probable that there are expelled from the roots certain substances, which having entered the plant and served their purpose in the organization, are of no further use, and therefore allowed again to pass out. We mentioned just now, that silica, the ingredient of which flints and sand are formed, requires to render it soluble certain quantities of alkalies, without which it could be of no service. As it cannot enter plants but in a state of solution, and as alkalies are necessary to render it soluble, it can never enter the vegetable tissue but in union with them, and in such proportion that a soluble compound be formed. When certain plants were analysed more silica was found in them than could be accounted for by the alkali present, so a conclusion was drawn that the alkali must have, when it had served its ends, returned again to the soil; or that the same quantity of alkaline substance had traversed and retraversed the vessels of the plant, depositing in its passage the silica which is held in solution, and returning again to the soil for a fresh supply.

The necessity of a rotation depends chiefly on the exhaustion of the soil of certain substances, though perhaps some slight bad effects may accrue from a retention of excrementitious matter in soils of a stiff and impervious nature, where the presence of oxygen is prevented by their want of porosity, and therefore

* Sprengel's Lehre vom Dünge, s. 26.

decay hindered from progressing. The more the soil is turned over and exposed to the decomposing agencies of air and water, the more rapidly will the ground be able to be grown with a crop similar to the one which had deranged its fertility; and the more readily will a new supply of food become as it were digested by the decomposition of the mineral masses in the soil. The length of the roots of plants also has much to do with this subject; when the surface land has been exhausted by a crop whose roots penetrate very slightly, another crop with longer roots, by going deeper, would be able to get at the nourishment which was beyond the reach of its predecessor. Hence we may frequently observe how very luxuriantly a plant of clover may flourish, while oats in the same situation would be sickly and weak, in every respect the opposite of the clover plant; the roots of the clover penetrate deep into the land, and outstrip in their search after food those of the oat—the former are often four feet or more in length, while the latter seldom go deeper than about eighteen inches.*

It was formerly supposed that only at the very extremities of the roots they could absorb nutrition, but it has been stated that by every part of the small prolongations this function can be performed. (Ohlert.) Doubtless the very small extremities absorb the greater part of the nutrition, as they will be found rapidly advancing in those parts of the soil most rich in nutritious matter, and they progress likewise with greater freedom wherever the ground is moistest and most porous. When in traversing the soil in search of food they meet with a spot deficient in nourishment, they die off in great measure; and the same thing occurs in winter, when only very small portions are left, which become the permanent or fibrous roots, which support the plant chiefly by their mechanical strength. The ramifications of the roots should be encouraged in every manner by making the soil pervious and easily penetrable, so that not the slightest obstruction, consistent with solidity, intervene.

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* Sprengel.

Besides the solid substances which roots gain from the soil in solution, there are doubtless received into them many gases, and in solution also. Putrefying bodies in the soil are ever eliminating quantities of nutritious gases, which at the moment of their production are dissolved by the water ever present, and by it carried into the circulation by the roots. The roots are not the only means by which plants are nourished ; much of their carbon is obtained from the air by the decomposing agency of the leaves. The spongy extremities of the small rootlets absorb the nutritious matter from the soil, and it is then conveyed through their tubes till it enters the larger branches of the roots; it is probable that the changes in the condition of the fluids absorbed commence as soon as they enter the circulation of the plant, and the organization becomes complete as the juices are deposited in the various parts of the tissues of the plants. The solutions of salts and earths are dissolved in the ascending sap, and after elaboration are combined, most probably chemically, with the other elements of the vegetable composition. It was once supposed that water was the substance from which plants elaborated their textures, and many experiments were founded to prove the correctness of this idea; we are now at least in a more likely winding of the maze that so bewilders our researches, but we hold in light the maxim "*ex nihilo nihil fit*," out of nothing can nothing be formed. From water we cannot make wood, and if we cannot tell how plants form the wood of their organization, we at least can tell of what elements it is composed, and by supplying these, aid in accelerating the performance of the functions of nature.

After the roots have performed that part of their duty, consisting in absorption of the water containing in solution the nutritious matter in the soil, the fluid commences to ascend through the thicker parts of the roots and enters the stem of the plant. The stems of those plants called *exogenous*, in which the thickness is increased by the deposition of new matter externally, consist of the bark, the alburnum, or sap wood, the duramen, or middle wood, and the pith. It is through the wood which has been last formed in the stem that the sap ascends that part which is called sap wood. The fluid that enters by the roots, passes upwards through the sap wood into the leaves, where it undergoes certain changes which we shall speak of presently ; being changed by the action it undergoes in the leaves, it descends through the inferior stratum of their vessels, and passes down the bark supplying on its passage the new wood, which is formed between it and the last or most external layer of the tree. Some of the sap goes also to the middle parts of the tree, conveyed thither by the rays of vessels which diverge from the centre and called the *medullary rays*. Descending through the bark, that part which is not needed in the elaboration of the tissues passes out of the roots, though for the most part this quantity is very small.

It may be very naturally asked here, what makes the sap, contrary to its own gravity, pass upwards through the stem ? Some have answered this question by attributing the phenomenon to the power called capillary, it being well known that very narrow tubes (capillary tubes, from *capillus*, a hair), when immersed in a fluid cause it to ascend in them above its level. This method of accounting for the phenomenon is very unsatisfactory, and others have endeavoured to explain it by supposing that the roots had some power of propelling the sap forwards ; this has likewise been proved to be incorrect, for the motion of the sap in spring commences in the buds and sprouts of the plant first, and then begins in the stem and roots.

The true cause of the sap rising in the stem we do not understand, but we can imitate its motion in glass tubes and artificial vessels ; if we take a long glass or pewter tube, the bottom of which is stopped up with a very porous piece of clay, we imitate to a certain extent a plant, the tube representing the stem and branches, and the porous piece of clay the spongy extremities of the roots ; we fill this tube with a solution of sugar of gum, or any salt to imitate the sap of a plant, and immerse the porous clay in a vessel of water. We, having thus rudely but essentially imitated the conditions of a growing plant, shall find that the water will rise in the tube, and continue to do so as long as there is a difference between the specific weight or density of the fluid in the tube, and the water into which it is dipped; and that the solution in the tube will even run over at the top, if the two fluids retain long enough their different specific gravities. Dutrechet found that the water in which the tube was immersed gradually contained the same substance as the tube, showing that the fluid enclosed in the tube must have passed through the porous clay ; this he called *Exosmose.* The entrance of the pure water into the tube from without he designated *Endosmose,* and he supposed that the cause of these phenomena was to be attributed to two electric currents. This we need not make a subject of discussion.

If the roots perform most important functions for the supply of nutrition to the growing plant, even these would cease to be developed were they not supplied with stores of food by the leaves. Not only do these organs modify and alter in composition the substances carried into them from the roots in the course of the sap, but they are continually during the day collecting from the air and water which surround them materials for the development of all the parts of the vegetable.

Leaves are said by physiologists to be the lungs of plants, but though they absorb gases from the atmosphere, their function is totally the reverse from that of the lungs of animals. The lungs of animals are an apparatus for the process of oxydation ; the leaves of plants by the aid of the sun's light and their own power deoxydise most bodies which enter their organization.* The under surface in the generality of plants is supplied with pores for the absorption of nutrition, and the upper surface is supposed to be that from which the excretions take place. This does not, however, hold good with all plants, and the grasses and such plants as grow on the surface of water, are exceptions, the former of which are supposed to be supplied with the necessary apparatus on both sides. The leaves, aided by the action of light, provide the plant with much of its solid material ; the decompositions of water and carbonic acid, the absorption of carbonate of ammonia, and other salts contained in solution in the water suspended in the air, or deposited on the plants, provide material not only for the nutrition of the leaves themselves, but supply the plants, even to the roots, with the varied compounds of their formation.

The function which plants possess of giving off from their surfaces the excess of fluids which they contain does not depend solely on simple evaporation. Exhalation may be distinguished from evaporation by the latter being common to all bodies exposed to an atmosphere dryer than themselves, while exhalation is a function confined to the living plant, and connected closely with the well doing and development of it. The leaves of all plants are covered with a skin which is called *cuticle*, that is to say, those plants which vegetate in the air, and one of the functions of this cuticle is to prevent the too excessive transpiration of the fluids of the plant; a branch removed from a tree and exposed would lose by evaporation the water which it contained, and the leaves would become flaccid and withered. The same is the case with plants which languish for water on a hot summer day, but if the branch were supplied with water at the fracture of the stem, or confined in a moist atmosphere, and the plants moistened at their roots, they both would soon recover the fluid which they had lost. Plants *exhale* water more under the influence of light combined with moderate heat than when exposed to greater heat in the absence of light; *evaporation* goes on with the greatest rapidity where the surrounding medium is dryest and the temperature greatest. Naturally, in summer exhalation is greater than in winter; evergreen plants exhale in summer as much in two days as in two months of the winter (Guettard). A sunflower which weighed three pounds lost on an average during fifteen days of warm weather, twenty ounces per day.

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* A plant of *Primula veris* grown in soil containing Hypo-sulphate of Soda gave out Sulphuretted Hydrogen.

A most interesting experiment made by Bishop Watson will serve beautifully to show of what immense importance this function of transpiration is in the vegeble world. He placed a glass vessel on a piece of grass land, from which the crop had been removed on a very hot day, and which had been subjected to a drought of many days' duration ; in two minutes the vessel became filled with watery vapor which condensed and ran down the sides ; this he collected, repeating the experiment for several days, between the hours of twelve and three o'clock, and calculated that one acre of grass even in this dry condition transpires in twenty-four hours, at least six thousand four hundred quarts of water.

Electricity and light have much to do with this function of exhalation ; plants in the full vigour of exhalation in a light situation cease to give out water when brought into a darkened room ; and plants subjected to the influence of artificial electricity exhale a third or fourth more than when left in a normal condition.

The sap, when it passes up into the leaves, is thin and watery, scarcely more in appearance than pure water, yet after it has undergone its important modifications in the leaves it is thick and glutinous, and contains all the proper juices and salts of the plant.*

If we placed a small animal under a glass vessel, and let it remain there till it died from the impurity of the air caused by its own respiration, the air would contain carbonic acid gas in large proportion ; and if we placed in the same vessel, exposed to the light, the branch of a plant in full leaf, we should find after a time that the air would again support animal life, and contain no more carbonic acid, but an equivalent quantity of oxygen. The same changes take place in the air on the large scale:—during the day the leaves of plants are continually taking in the carbonic acid which plants are sending out, keeping the carbon and evolving the oxygen of which the carbonic acid is composed.*

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* The leaves not only exhale aqueous vapour from their surface, but in many instances they are found to give out substances which are either carried into them by their circulating fluids, or formed in their tissues. Some plants exhale ammonia, some scent the surrounding atmosphere with the volatile oils which they secrete, but they all agree in evaporating and exhaling water and expiring oxygen. I find also that plants watered with solution of iodide of potassium give out iodine from their leaves, implying of course the assumption of oxygen.

There are contained in the air in suspension, water, carbonate of ammonia, and many other substances, all of which can be absorbed into the circulation of plants by the leaves. There are many reasons for supposing that the leaves of plants are a sort of galvanic battery, of which the upper and undersides are the poles, for most of the compound bodies which enter them either by their own pores, or through the medium of the roots, are decomposed in a striking manner. Common salt consists of chlorine and sodium, and plants grown in soils containing much salt, give out chlorine from their leaves ;* and no doubt exists but that many earths and oxydes taken into the plants by the roots, are by the action of the leaves decomposed, their oxygen being evolved, and their other elements taken into the organization of the plant.

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* It has been said, that the emission of carbonic acid at night by plants was, like the evolution of oxygen by day-light, a function of the leaves, and the circumstance is generally mentioned as a function of the leaves in the absence of light. It is, however, no function of organization, it is the chemical action of certain bodies producing its normal result. It matters not if the leaf be entire, or whether it be mashed in a mortar to a pulp. It is a simple chemical action, this evolution of carbonic acid when the plant is not under the influence of the exciting cause, a gradual conversion of its carbon and hydrogen into carbonic acid and water, and a fixation of a certain excess of oxygen in the form of an oxygenized vegetable body. If a plant is shut up from light and exposed to oxygen, oxydation takes place, and carbonic acid is evolved and oxygen compounds are formed; if the plant be exposed to the light, its true functions of vitality are in full activity. In certain plants, as in the *Cotyledon calycynum* and *Cacalia ficoides*, there is found in the morning an acid formed during the night by the high state of oxydation of some one or other of the ingredients of the plant; when however the functions of the leaves are restored by the return of light, the reductive action commenced, the oxygen is either evolved or new quantities of carbon are conjoined with the nocturnally-formed acid, and it is consequently reduced towards mid-day to neutrality, and as the day progresses the changes made in the composition of the parts are more evident, for the plant which at *morning* is acid in taste, at *mid-day* is tasteless, and at *evening* is bitter, the last character being dependent on the assimilation of fresh quantities of carbon and hydrogen, and the evolution of proportionate volumes of oxygen gas.

The changes that are made by the leaves in the arrangement of the elements of the bodies which enter their tissues, are supposed to take place in fleshy part under the external covering, and they are various and interesting. We have seen in what a simple manner the food of wild plants is supplied to them, from the changes which progress in the matter around them.

A plant is to a certain extent a laboratory, in which is prepared the food of animals; it is furnished with vessels and apparatus amply suited for the purposes of its existence, and serves by its intermediate qualities as a connexion between inorganized matter, and beings of the most elaborate construction.† In our cultivation we give to plants the same materials as they find in a wild state, and these they make into bread. When the sap has been elaborated in the leaves and vessels of the extremities, it is suited to deposit in the tissues all the compound bodies which compose them. The functions of plants and animals ever tend to one most important fulfilment, the formation of beings to occupy their places, when in the natural course of events they have decayed. Every plant almost has a manner differing in some particular from others in the progress of its development, but the termination of all their modified functions is the same, the production of seed.

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* Sprengel.—See note page 105.

† What we allude to is the following :—Carbon, hydrogen, and nitrogen, are converted by their own properties and by causes of a purely chemical nature without the assistance of vitality, into carbonic acid and ammonia; a purely chemical process prepares tha food of plants. In plants carbonic acid, ammonia, and water, undergo other unions and decompositions, the chemical progress is *perhaps* assisted by the power termed vitality, and much more complicated combinations are produced. All the vegetable com-

The functions of the roots, combined with the continued action of the vital and chemical processes of the leaves, from the simply formed chemical compounds, carbonic acid, water, and ammonia, produce all the ingredients that compose the perfect plant.

As the substances formed by the processes of plants are the chief support for man, and the animals domesticated by him, we shall in conclusion describe some of their leading properties.

The stem, the bark, the leaves, and the roots, have a foundation of a tough stringy substance, which is called woody fibre; this fibrous matter is arranged in such a manner as to give mechanical support to all those parts into the composition of which it enters; all the tubes, passages, and cellular masses of plants are formed of woody fibre, serving to form passages for the circulation of the fluids, which convey nourishment to the organs and fruit. Woody fibre is found in almost

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pounds are the food again of animals, and they are so constituted as to be assumed as part of their organization with the greatest simplicitude. The carbonic acid is decomposed by the leaves, the water also; and the ammonia supplies the nitrogen; so there are formed starch, albumen, sugar, &c. the food of animals.

every part of the plant, forming the stem, the nerves of the leaves, and the fibres of the bark, and it is to it that they owe their strength and toughness. Woody fibre in its pure state has received from chemists the name of *Lignin ;* from whatever plant it has been procured, it has always the same composition. It is composed of carbon united to the elements of water, and does not contain any nitrogen.*

The cells and cavities formed in the plant by the woody fibre are filled with different substances and fluids, some of which are common to all vegetable productions, as starch, sugar, gum, fibrine, albumen, and caseine, and others which are peculiar to certain plants, as for example turpentine to the fir tribes.

We may perceive, on referring to the note below,

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* The Lignin of Chemists is prepared by washing wood with spirits of wine, and some dilute acid to deprive it of resinous and saline impurities. When thus prepared and pure, it gives, when it is analysed, the following composition :—

Carbon................	50.50
Hydrogen.............	5.05
Oxygen...............	44.45
	100.00

When wood decays there are produced carbonic acid and water (it will be remembered that carbonic acid is composed of carbon and oxygen, and that water consists of oxygen and hydrogen.) We have said that all bodies decaying absorb oxygen, and we may here state that all analogous compounds to the above give out oxygen to the air during their formation in the plant. We can perceive how in the formation of such a body as this from carbonic acid and water, how much oxygen is sent into the air from the plant. Supposing that all the hydrogen was obtained in the form of water, for every 5lbs. of hydrogen require about 44lbs. of oxygen to convert them into that fluid, then there will remain 50.50lbs. of carbon, which would require about 132lbs. of oxygen to convert it into carbonic acid. So that a tree in forming 100lbs. of woody fibre would give out to the air 132lbs. of oxygen.

how by the condensation of carbonic acid in the cellular parts of the leaves, the evolution of oxygen by them, and the deposition of woody fibre in the various parts of the plant, may be accounted for, and it will be no less easy to recognize the same phenomena, attended with the same results, in the production of the three other substances named above, starch, sugar, and gum. It is the function of the leaves to prepare these substances, and at the same time to renew the salubrity of the air, by depriving it of its carbonic acid.*

Starch is the next most abundant, and perhaps important of that class of bodies, formed by the addition of carbon to the elements of water; the fruits, seeds, and in many instances the roots and stems of plants contain large quantities; it is evidently formed as a product of the deoxydizing properties of the functions of the leaves. Many plants contain it in all parts of their organization, and since starch can to a certain extent support animal life as an article of food, the bark of trees is used in arctic countries in times of scarcity. The willow plant contains much starch, and is very easy of propagation, because like the seed it has a store of nutrition at hand to supply the necessities till the leaves and roots are perfected.

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* Woody fibre; cotton, hemp, flax, and paper, are varieties of woody fibre and have the same composition; cotton is the product of trees which are natives of tropical countries (chiefly the different species of *Gossypium*); it has the same composition as the other varieties of woody fibre; hemp is the fibre of the stalks of the *Canabis sativa;* flax, which is a substance of the greatest importance as the product of a plant which is daily increasing in the extent of its cultivation in this country, is prepared from the fibres of the stalks of the *Linum usitatissimum* by the process termed *retting*, which consists in allowing the stalks of the plant to be exposed to the action of water and air, till by the decay of the intercellular matter their fibres may be easily separated; lastly, paper is the manufactured product of any of the above forms of woody fibre, and has the same composition.

The leaves supply the roots with starch ; and not only with starch but with woody fibre, and also with the elements of many other of their constituents. The tubers of the potatoe contain from 12 per cent. of starch, and there is not the least doubt that much of the carbon contained in it is obtained from the air and not from the soil. Some have, with purblind acuteness, recommended that the leaves should be picked from potatoes and beet root, to make the roots grow larger, forsooth that the growth of the leaves might not exhaust the plant. We should suppose that if the potatoes were larger it was because they were filled and distended in their cellular interstices with aqueous matter, which, as the leaves could not exhale it, was suffered to remain. If it is allowed that all the carbon and hydrogen of plants are derived as carbonic acid and water, and that only the leaves and small extremities could cause the transformation of these bodies into starch, and similarly constituted substances, how could other bodies be formed when the leaves were cut off ? Such practice resembles the mutilation of a man in one way or other, which causing dropsy would make him believe that he was getting fat.*

The leaves are of as great importance to the plants as any other of their parts ; they exhale the excess of fluid from the rising sap, and when they cease to exhale the roots cease to absorb; they decompose the gases that surround them, and those that are carried into them by the circulation of the stem, and yet it has been supposed that it would be better to cut them off that they may not weaken the plant!

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* "Three separate portions, each seven yards long and one wide, (that is, seven square yards), of mangel wurzel were selected, where the plants on the ridges appeared to run as nearly alike as possible. Four or five of the under leaves were stripped, upon three separate occasions, from the plants on one of them (A), viz. on July 8, August 6, and first week in September; from another of them (B) on two occasions, viz. August 6, and first week in September ; and none were stripped from the third ridge (C).

The roots were carefully cleaned and weighed, and the produce was as follows:—

	lbs.		tons.	cwt.	qrs.	lbs.	
From A	47½	neat weight, or	14	13	0	27	per acre.
B	52	....	16	1	0	2	
C	61	....	18	16	2	9	

So far this experiment speaks for itself, and I dare say its language is sufficiently intelligible not to need an interpreter. Now I do not even yet presume to allow science to boast herself over practice from the result of this single experiment; for I do not know to what extent the practice alluded to any where prevails. I merely produce the experiment in illustration of what I have been saying of the function of the leaf, and in contradiction to the very commonly admitted notion that the root directly nourishes the leaf, and not the leaf the root. If each member of the jury whom I have invited to test the utility of pulling leaves off mangel will only consent to play the part of executioner, and, after torturing a certain number of plants, will be so good as to favour me with the result in the form of comparative experiments, more or less like the one above, I shall be happy to report upon them, and state to what extent you may possibly expect to increase your produce by the practice, or to what extent you may perhaps be able to succeed in diminishing it. It was not an unfrequent practice in the unhappy days of the feudal ages (may their like never return!) for our bold Barons to put unlucky Jews to torture whenever they could catch hold of them, and could not prevail upon them by fairer means to produce a certain amount of cash from their pockets; and so, perhaps, we shall find that some non-baronial experimenter of these our own days, of somewhat advanced and advancing intelligence, may discover a harmless mode of torturing a mangel, so as to force it to yield more nourishment by foul treatment than it may be disposed to do by fair means. But I will not be so unphilosophical as to anticipate the result of our projected experiment."—*Henslow.*

Starch * is somewhat similarly constituted to woody fibre, and contains in like manner the elements of water combined with carbon. In the living plant starch is a most important substance, supplying most probably by its transformations all the ingredients which bear any analogy to it in composition, such as wood, sugar, gum, &c.

Starch has the following composition :—

Carbon	43.55
Hydrogen	6.77
Oxygen	49.68
	100.00

The exudation from some plants, a familiar example of which is afforded by the cherrytree, is gum ; gum enters into the composition of almost all parts of the generality of plants, and is in composition very similar to starch. Like the above and woody fibre it contains no nitrogen, and cannot alone support animal life. It is composed, according to Berzelius, of—

Carbon	41.90
Hydrogen	6.78
Oxygen	51.30
	100.00

bearing much resemblance, it will be observed, to starch and woody fibre.

Sugar is the next most interesting of the bodies contained in plants in sufficient abundance as to become

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* Sago, Tapiaco, and Arrowroot are varieties of starch, and great quantities are procured in this country from the potatoe ; it is now generally manufactured by machinery, and good red potatoes or the sweet varieties yield from 16 to 18 per cent. Starch is endowed with some most peculiar properties ; it can, by the action of many substances, be converted into sugar. We have seen an instance of this transformation in the germination of a seed.

useful as food, and produced by them by their chemical functions. It exists in greater or less proportion in almost all plants, from some of which it is procured as an article of commerce and consumption, while from others it is made use of indirectly in the production of spirituous liquors. The plants which chiefly yield sugar as an article of commerce are the sugar cane, *Saccharum officinarum;* the sugar maple, *Acer saccharinum;* the common beet root, *Beta vulgaris;* and Professor Croft, of Toronto, has mentioned that large quantities may be and are procured from the stalks of the Indian corn, *Zea mays.* Grapes and fruits generally contain a particular kind of sugar called grape sugar, and yield wine by fermentation, at the expense of the sugar. Honey and manna are likewise varieties of sugar, and the products of the vegetable economy. In plants generally speaking the sugar exists in the form of starch, and as the fruit advances towards maturity, by conversion, their sweetness increases.

Sugar has a composition very similar to these other bodies which we have described—

Carbon	42.47
Hydrogen	6.90
Oxygen	50.63
	100.00

When sugar is mixed with water and a little yeast added to the solution, it commences to undergo the process of fermentation, the elements of which it is composed enter into new forms of union, and other organic bodies are produced, the chief of which is alcohol or spirits of wine. The sugar commences to change the arrangement of its elements from a motion conveyed from the molecules of the yeast (which is gluten, the nitrogenized part of wheat, in a state of decomposition.) Many substances may be converted into sugar by the action of certain bodies; we have seen that starch is transmuted in the germinating seed into sugar, and the same change may be brought about by the action of diluted sulphuric acid or oil of vitriol. If starch or woody fibre in any of its conditions is boiled for a continued space of time with diluted sulphuric acid it is converted into the modification of sugar, which is called sugar of grapes.

Sugar of grapes either obtained artificially or from many vegetables which contain it, has a composition very similar to that of the common sugar of the sugar cane. It is composed of:—

Carbon	36.36
Hydrogen	7.07
Oxygen	56.57
	100.00

There are many other sources of sugar, and a variety exists in milk, called Sugar of Milk. These are the chief bodies which constitute the non-nitrogenized parts of plants; they are of very simple composition and are formed of the elements of water united to carbon; it is not improbable that any one of them may be converted by the vital chemical processes into the other; we can artificially convert starch or wood into sugar, and we may suppose it not improbable that changes of a similar nature may progress in the living plant.

It is evident to the senses of any one who enquires, that no sugar or starch, or gum, or woody fibre, exists in the soil, and that therefore these could not enter the organs of the plants as such; indeed we must suppose that wood must have been in some soluble condition before it was deposited in the various parts of the plant, and received its hardness after its deposition. The similarity of composition of the vegetable world is great, and if we exclude those substances which individualize certain tribes or species of vegetables,* the number of compounds is very small.

We have not yet spoken of those fatty and oily bodies which exist in some plants in an abundance worthy of consideration, but we shall not take up time with their description, remarking only that they are destitute of nitrogen, and are similarly constituted to the bodies we have just described, differing slightly in the number of the atoms of the elements of which they are composed. They all contain large quantities of carbon and hydrogen. Many resins and volatile oils of somewhat similar compositions are likewise to be found in many varieties of plants.

Accompanying sugar, starch, and the other non-nitrogenized substances in the organs of plants, are others which contain nitrogen as a chief element of their composition. We have noticed how in the seed the albumen was converted into diastase, and thus a change induced in the condition of the other ingredients; though these bodies which contain no nitrogen exist in the greatest quantity, in fact, form the great bulk of the vegetable world, yet they are of secondary consideration in the art of cultivation for the purposes of food. The nitrogenized ingredients are those which are organized in the plant for the food of the animal creation, and exist in all plants, though in a less quantity than the others, or non-nitrogenized. These substances exist in plants, and when devoured by animals are assimilated without being altered in composition; they have received from chemists the names of vegetable fibrine, vegetable albumen, vegetable caseine, and vegetable gluten, the word *vegetable* implying the source from whence they may have been derived. They contain besides carbon, hydrogen, and oxygen, nitrogen, sulphur, and phosphorus. The names that have been applied to them are derived from those similarly constituted bodies in the animal economy: blood when beaten and agitated separates from itself a fibrous adhesive matter, hence called *fibrine;* albumen, or the white of egg ; caseine from forming the chief part of cheese ; and gluten, which exists in wheat, from its glutinous properties.

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* As opium the poppy, and turpentine the fir tree.

When wheat flour is worked in the hand till only a stiff glutinous matter remain, which can be drawn out into threads, and is stiff and elastic, that substance is *gluten* of *wheat.* Wheat on an average contains about 22 p.c. of gluten, more or less, according to its goodness; rye about 11 p.c. barley about 5, and oats about 4. If gluten is boiled in alcohol, or spirit of wine, there is left behind a material somewhat similar, and called vegetable fibrine. Albumen is found in the water which has been used to wash the flour in obtaining the gluten ; it is soluble in water in the cold, but when the water is heated it becomes coagulated, like the white of egg, from which it derives its name, albumen. Vegetable caseine, or cheese, is obtained from the seeds of peas and beans, and similar plants ; it resembles fresh made curds of cheese, and hence called caseine. All these bodies are most important, and supply the animals which feed on them with *all* the flesh they contain ; as flesh contains nitrogen, it can only be formed from substances which likewise contain this element. We speak of *flesh* in contradistinction to *fat;* the latter in graminivorous animals is obtained from the food in the form of starch, &c. the former as the bodies above described.

The changes taking place in the interior of plants are indeed wonderful, and sometimes the transmutations progress with such rapidity as to be astonishing; we noticed a little way back instances of plants which we mentioned as being acid at one period, bitter at another, and tasteless at an intermediate one ; and it may have been observed that cattle devour with much more avidity grass at certain periods of the day than at others, and we may even suppose that the bitter principle, formed as we mentioned by the deposition of carbon, could be of great tonic influence on the cattle, giving them all the exciting impulses which tonics produce when administered to man.

The changes which take place in the leaves go in during the life of the plant in some species, while they are terminated in many for a period at the approach of winter; but before death there are provided resources for the production of a fresh crop, or new individuals to carry out the purposes of their predecessors.

At the periods of inflorescence and fructition, the plant developes certain organs to produce seed, forming what is commonly called the flower; the flower generally consists of an external green case, and an internal coloured one, though in many examples both are green ; the external one is termed the *calyx*, the internal the *corolla*, or flower. These, however, are not the organs absolutely necessary in the reproductive processes ; the organs called *stamens* and *pistils* fulfil the necessary functions, in conjunction with a vessel to receive or contain the seed.

The stamen is provided with a peculiar substance called pollen, which it generally sheds on the pistil, causing impregnation, and inducing some peculiar changes to progress, and ultimately the production of fruitful seed. Sometimes the pistil and stamen are placed on different plants of the same species, those bearing flowers with pistils being called female, and those with stamens male. The impregnation of the *ova*, or germ contained in the seed vessel, being consummated by the aid of the winds, or insects which might have been attracted to seek for honey in the blossoms of the plants in question.

The functions of the organs of generation as regards the reproduction of the species, is involved in the darkest obscurity: that a plant from which either the stamens or pistils are removed, will not bear seed is a well known fact, but if the pollen of another individual be placed in contact with the pistil of the flower whose stamens had been removed, it would then be fruitful. *Whether the pollen, at the moment of its application, (or soon after) induces a sort of motion in the molecules of the ova, bearing analogy to the production of sugar from starch by diastase, is a curious subject for consideration.* The process of fermentation is either slow or fast, according to circumstances, and it may be that the changes once commenced by the chemical action of the pollen, may progress till the full development of the seed; this, however, is perhaps a somewhat wild notion, and must not be adopted without much more consideration than it has yet received. However this may be, it is well known, that at the time of reproduction the energy of the plant is devoted to the maintenance of this most important process, and that even the life of the individual is destroyed by the effort necessary, or much shortened by the perfecting of its seed. An annual plant may be made to live for a long period of years, by continually removing the flower buds as they appear.

The flower leaves or petals of plants do not possess the functions of the green ones; they do not decompose carbonic acid, but on the contrary they absorb oxygen from the air and give out the former gas. It may be, for the fact is not ascertained, that the production of carbonic acid may be the means of providing a temperature somewhat higher for the assistance of the chemical changes which take place in the flower during the period of its existence. When the function of generation and fruition is complete, there is formed a perfect seed, in every way capable of reproducing, by recommencing the same changes, plants similar to that from which the seed was obtained.

Though in some degree as all these processes may seem in the profoundest obscurity, displaying as they do the most minute and splendid regularity, they must convey to our minds, in their even superficial study, the great things to be gained by a more perfect acquaintance with them; how many beautiful and eminently useful domestic and economical investments of time we might make if we only devoted a little to the consideration of the laws of nature. The man who loves knowledge for her own high charms, has sufficient reward when he walks a little way with her through nature; the man of industrial occupation, if the pleasure of knowing is not a perfect inducement, may consider how much is to be gained in power, wealth and comfort, by a search into the ways of nature, which have been so often found leading to distinction, as pointing out the means of obtaining by her assistance what otherwise could only be procured with the greatest labour and anxiety.